Tax Competition Among U.S. States:
Racing to the Bottom or Riding on a Seesaw?

Robert S. Chirinko
(University of Illinois at Chicago, CESifo, and the Federal Reserve Bank of San Francisco)

and

Daniel J. Wilson
(Federal Reserve Bank of San Francisco)

Current draft: May 2015

Acknowledgements:
We would like to acknowledge the excellent research assistance provided by Charles Notzon and the comments and suggestions from participants at the American Economic Association meetings, the CESifo Area Conference On Public Sector Economics, the Econometric Society World Congress, the Federal Reserve System Conference on Regional Analysis, the International Institute of Public Finance meetings, the *Journées d'Économie Publique Louis-André Gérard-Varet*, the National Tax Association meetings, the Western Regional Science Association meetings, and from seminar participants at the Barcelona Institute of Economics (IEB), Baylor, Bergamo, Davis, Deakin, Goethe, Kentucky, Max Planck Institute for Tax Law and Public Finance, Michigan, Monash, Nevada-Reno, Oxford, and Pompeu Fabra. Very useful comments have also been provided by Don Andrews, Thiess Büttner, Raj Chetty, Kelly Edmiston, Don Fullerton, Andrew Haughwout, Ross Hickey, Jim Hines, Jan Kiviet, Kai Konrad, Dan McMillen, Tom Mroz, Tom Neubig, Marko Koethenbuerger, Hashem Pesaran, Adam Shapiro, Giovanni Urga, and Jay Wilson. Financial support from the DAAD, the Einaudi Institute of Economics and Finance, the Federal Reserve Bank of San Francisco and the IEB is gratefully acknowledged. Chirinko thanks the Einaudi Institute of Economics and Finance, the European University Institute, and Goethe University and Wilson thanks the IEB for providing excellent environments in which to undertake this research. All errors and omissions remain the sole responsibility of the authors, and the conclusions do not necessarily reflect the views of the organizations with which they are associated.

Tax Competition Among U.S. States:
Racing to the Bottom or Riding on a Seesaw?

Abstract

Dramatic declines in capital tax rates among U.S. states and European countries have been linked by many commentators to tax competition, an inevitable "race to the bottom," and underprovision of local public goods. This paper analyzes the reaction of capital tax policy in a given U.S. state to changes in capital tax policy by other states. Our study is undertaken with a novel panel dataset covering the 48 contiguous U.S. states for the period 1965 to 2006 and is guided by the theory of strategic tax competition. The latter suggests that capital tax policy is a function of "foreign" (out-of-state) tax policy, home state and foreign state economic and demographic conditions and, perhaps most importantly, preferences for government services. We estimate this reaction function with Pesaran's Common Correlated Effects estimator to allow for heterogeneous responses across states. The slope of the reaction function – the equilibrium response of home state to foreign state tax policy – is *negative*, contrary to many prior empirical studies of fiscal reaction functions. This seemingly paradoxical result is due to two critical elements – controlling for aggregate shocks and allowing for delayed responses to foreign tax changes. Omitting either of these elements leads to a misspecified model and a positively sloped reaction function. Our results suggest that the secular decline in capital tax rates, at least among U.S. states, reflects synchronous responses among states to common shocks rather than competitive responses to foreign state tax policy. While striking given prior findings in the literature, these results are not surprising. The negative sign is fully consistent with qualitative and quantitative implications of the theoretical model developed in this paper. Rather than "racing to the bottom," our findings suggest that states are "riding on a seesaw." Moreover, tax competition may lead to an increase in the provision of local public goods, and policies aimed at restricting tax competition to stem the tide of declining capital taxation are likely to be ineffective.

Keywords: Tax Competition, State Taxation, Reaction Functions, Capital Taxation

JEL Codes: H71, H77, H25, H32

Corresponding Author: Robert S. Chirinko, Department of Finance, University of Illinois at Chicago, 2333 University Hall, 601 South Morgan (MC 168), Chicago, Illinois 60607-7121, EM: Chirinko@uic.edu, PH: 312 355 1262 , FX: 312 413 7948

Daniel J. Wilson, Research Department, Federal Reserve Bank of San Francisco,
101 Market Street, San Francisco, CA 94105,
EM: Daniel.Wilson@sf.frb.org, PH: 415 974 3423, FX: 415 974 2168

Tax Competition Among U.S. States:

Racing to the Bottom or Riding on a Seesaw?

Table Of Contents

Tax Competition Among U.S. States:
Racing to the Bottom or Riding on a Seesaw?

> Wisconsin is open for business. In these challenging economic times while Illinois is raising taxes, we are lowering them.
>
> Governor Scott Walker of Wisconsin (January 12, 2011)

I. Introduction

This paper provides an empirical analysis of an important element in the theory of strategic tax competition, the reaction of capital tax policy in a given jurisdiction to changes in capital tax policy by neighboring jurisdictions. The analysis is motivated in part by the dramatic decline among industrialized countries in capital tax rates over the past few decades. There has been much debate over what factors are causing this decline and, in particular, how much of it is due to competition among jurisdictions. A number of cross-country empirical studies have attempted to identify the causes, but this research faces challenges from the substantial heterogeneity across countries in institutions, regulations, and business environments that weigh heavily on tax policy and impede capital flows. U.S. states provide an ideal laboratory for investigating the determination of capital tax rates and the role of tax competition because, while states have much latitude for setting their own capital tax policies and do, in fact, set widely varying tax policies, they share many important institutional and environmental factors in common. Moreover, the general downward trend in capital taxation observed among industrialized countries in recent decades has also been observed among U.S. states.

This trend among states can be seen in Figures 1 through 4, which show national averages of the major state capital tax policies from 1969 to 2006. In 1968, no state had an investment tax credit (ITC). Since then, as shown in Figure 1, ITC adoptions have grown steadily; by 2006, 24 states have or have had an ITC, and the average rate among states with an ITC has risen considerably to over 4%. Figure 2 displays the average ITC and corporate income tax (CIT) rates over all states. The national average ITC rate has increased in a nearly monotonic fashion and reaches nearly 2.0% by the end of the period. While the average CIT rate increased from the beginning of the period until 1991, it has fallen moderately since then. The impact of these two tax variables on the incentive to acquire capital can be measured by the tax wedge on capital (TWC), which is the tax component of the user cost of capital.[1] Figure 3 documents that the average TWC has fallen in recent years. This pattern is confirmed by two additional tax series displayed in Figure 4. The capital apportionment weight (CAW) is the weight on capital in a state's formula for apportioning national corporate income to the state; similar to a lower CIT rate, a lower CAW may provide an incentive to locate capital in the state. The average CAW series has fallen sharply, declining by approximately 10 percentage points. An alternative perspective on capital tax policy is provided by the average corporate tax (ACT) rate, defined as the ratio of corporate tax revenues to corporate income. As shown in Figure 4, the average ACT peaked in 1980. Since then, this procyclical series has drifted downward. Viewed from a variety of perspectives, state capital taxation has changed dramatically in recent years and has become more "business friendly." These aggregate movements, buttressed with anecdotal observations and past empirical studies, suggest to many observers that states are engaged in a "race to the bottom."

The empirical results in this paper challenge that conclusion. We find that the slope of the reaction function – the equilibrium response of home state tax policy to foreign state tax policy – is *negative*. This result – articulated in the quotation above from the Governor of Wisconsin – runs contrary to the casual empirical evidence in Figures 1 through 4, the findings in many prior empirical results, and the implications of some theoretical models. We document that this seeming paradox is due to two critical elements omitted in most prior empirical studies. First, aggregate shocks affecting all states create common incentives that lead states to act synchronously. Absent proper conditioning for aggregate shocks, a positive slope of the reaction function is obtained with our data. Second, in theory, tax competition is driven by capital mobility among states, but the flow of capital is not instantaneous, instead occurring over several years. A properly specified model needs to allow for lagged responses. In our data, static models also generate a positively sloped reaction function. When we condition on aggregate shocks <u>and</u> allow for delayed responses, we find that the tax reaction function is negatively sloped.

While this result is striking, it is not surprising and is fully consistent with the qualitative and quantitative implications of the theoretical model developed in this paper. Our findings suggest that the dramatic declines in state capital taxation in recent decades are not driven by tax competition among states, but rather from aggregate shocks (e.g., tax rates and input costs

---

[1] The *TWC* series equals $\left\{\left[\left(1-ITC-CIT\cdot TD\right)\ /\ \left(1-CIT\right)\right]\ -\ 1.0\right\}$, where *TD* is the present value of tax depreciation allowances and ITC and CIT reflect only state taxes. See Appendix A for details.

abroad, U.S. macroeconomic conditions, the capital income share) impacting all states in more or less the same manner. Rather than states "racing to the bottom" (a competitive response of tax rates in the same direction), our results suggest that state tax competition is better characterized by states "riding on a seesaw" (a competitive response in the opposite direction).

Whether states are "racing to the bottom" or "riding on a seesaw" is important in current policy debates, both in the U.S. and abroad. Many analysts and policymakers point to the secular decline in marginal and average capital tax rates (documented in Figures 1 to 4) as "proof" that states are engaged in a harmful race to the bottom necessitating federal legislation or judicial action. For instance, a 2006 Supreme Court case, *Cuno v. DaimlerChrysler*, centered on whether state investment tax credits are a form of harmful tax competition and could run afoul of the Commerce Clause of the U.S. Constitution.[2] In recent years, the U.S. Congress has considered several bills that would alter states' capacity to set various capital tax policies independently. The severe budget strains on many state governments during the Great Recession and its aftermath further heightened concerns that interstate tax competition was "forcing" states to forego badly needed tax revenues at a time when spending on automatic stabilizer programs was rising and personal tax revenues were falling sharply.[3]

State business taxes and their implications for tax competition are also relevant for current policy debates in Europe.[4] As mentioned above, corporate tax rates among OECD countries also have declined sharply over the past two or three decades (Devereux, Rodoano, and Lockwood, 2008, Figure 1; U.S. Treasury, 2007, Chart 5.1). This decline has led to deliberations among European Union (EU) officials over whether to impose tax harmonization measures (McLure, 2008). As intra-union capital mobility rises toward levels approaching that among U.S. states, the U.S. experience may help inform the EU debate. Our results based on U.S. states suggest that policies aimed at restricting tax competition as a means of stemming the tide of

---

[2] The U.S. Commerce Clause states that "The Congress shall have Power … To regulate Commerce with foreign Nations, and among the several States, and with the Indian tribes; …" (United States Constitution, 1787, article I, section 8). See Enrich (1997) and Stark and Wilson (2006) for discussions of the Commerce Clause and its relation to tax policy.

[3] The cost of state and local business tax incentives and their importance for business location decisions was the subject of a series of articles in the New York Times (Story (2012)).

[4] The restrictions in the U.S. Commerce Clause are echoed in the Treaty of Rome section on *Aids Granted by States*: "Save as otherwise provided in this Treaty, any aid granted by a Member State or through State resources in any form whatsoever which distorts or threatens to distort competition by favouring certain undertakings or the production of certain goods shall, in so far as it affects trade between Member States, be incompatible with the common market" (Article 87).

declining capital taxation are likely to be ineffective. If aggregate shocks, not tax competition, are driving the secular movements in capital taxation, the elimination of tax competition will do little to stop or reverse these trends.

Our paper proceeds as follows. Section II develops a theoretical two-region model of capital taxation whose key element is the relative preference of residents for private vs. public goods. We show that the sign of the slope of the reaction function of home state to foreign state tax policy depends on the income elasticity of private goods relative to public goods. To develop intuition for this important result, consider the case when the capital tax rate for a neighboring state rises. In turn, mobile capital (eventually) flows into the home state and the tax base rises. If the income elasticity of private goods relative to public goods is sufficiently positive, then residents will prefer to use this income "windfall" to finance a tax cut – a negative or "see-saw" tax reaction – allowing higher private good consumption while still maintaining current levels of public good provision. Alternatively, if the income elasticity of private goods relative to public goods is negative, then residents will prefer to use the windfall to disproportionately increase public good consumption, necessitating a higher capital tax rate – a positive or "race to the bottom" tax reaction. Thus, the slope of the reaction function depends on whether private goods as a whole are a luxury or necessary good or whether Wagner's Law is valid. Apart from the ambiguity of the sign of the slope, the theoretical model has an additional implication that the absolute value of the slope increases with the mobility of capital. Tax instruments that target new, highly-mobile capital (the ITC) should have larger reaction function slopes than do instruments targeting old, less mobile capital (the CIT).

Section III presents the estimating equation. As we shall see below, the effects of aggregate shocks prove critical in evaluating the reaction function. We go beyond the standard time fixed effects estimator that constrains responses to an aggregate shock to be homogeneous across states. Instead, we employ the Common Correlated Effects (CCE) estimator (Pesaran, 2006) that allows for heterogeneous responses across states. Additionally, the theory of tax competition strongly implies that there will be an endogeneity problem with estimating the slope of the reaction function. This estimation problem is addressed with a novel procedure that selects instruments based on their relevance.

Section IV and Appendix A discuss our panel dataset for the 48 contiguous U.S. states for the period 1965 to 2006. This dataset has the virtues of a substantial amount of cross-section and time-series variation for an economic environment that is relatively free of impediments to the flow of capital. We have data on five tax variables – the investment tax credit, the corporate income tax rate, the tax wedge on capital, the average corporate tax rate, and the capital apportionment weight – and a set of political, demographic, and economic variables to serve as controls and instruments.

Section V presents our empirical results that document the importance of controlling for aggregate shocks and delayed responses. When the econometric model does not control for either of these elements, we obtain a positively sloped reaction function, as reported in most prior work. When both time fixed effects and time lags enter, the reaction function has a negative slope. These results are robust in several dimensions, including measuring capital income taxation by the tax wedge on capital. Moreover, consistent with a theoretical prediction from our model, the slope is larger (in absolute value) for the ITC relative to the CIT. We also explore the impact on our estimated reaction function of including additional tax variables.

Section VI offers a brief discussion of some of the relevant literature on reaction functions. Section VII summarizes how our “riding on a seesaw” finding informs policy discussions concerning tax competition and capital mobility.

II. The Tax Reaction Function: Theoretical Underpinnings And Empirical Implications

This section develops a model of strategic competition and extracts implications for the tax reaction function – the equilibrium response of tax policy in a home (in-state) jurisdiction to tax policy in a foreign (out-of-state) jurisdiction. We show that the slope of the reaction function can be positive (“racing to the bottom”) or negative (“riding on a seesaw”) and that the sign of this slope depends on the sign of one key parameter – the income elasticity of private goods relative to public goods. The sign of this elasticity is related to whether private goods as a whole are a necessary or luxury good or, alternatively, whether Wagner’s Law is valid. The model developed in this section is useful for identifying the determinants of the slope of the reaction function and motivating the model to be estimated and interpreted in the empirical section of this paper.

A. A Model Of Tax Competition

Our model of tax competition is based on six relations that describe the constraints faced by a government choosing business capital tax policy to maximize the utility of the representative domestic household. First, production in the home state is determined by a Cobb-

Douglas function that depends on a mobile capital stock and a fixed factor of production, such as labor, land, infrastructure, or a composite thereof. The capital stock available for home production (K) is the sum of the capital stocks owned by home residents (k) and, given the mobility of capital, the capital stock owned by foreign residents but located in the home state (k^f).[5] We write the production function ($F[K]$) in the following intensive form relative to the fixed factor of production (note that brackets are used in this paper to identify arguments in functional relations),

$$y = F[K], \tag{1}$$
$$K \equiv k + k^f,$$
$$F'[K] > 0,\ F''[K] < 0.$$

Second, as a result of capital mobility, the capital stock in a given state is sensitive to capital income tax rates prevailing in home and foreign states. Consequently, the capital stock in the home state depends negatively on the home capital tax rate (τ) and positively on the foreign capital tax rate (τ^f), as well as on a set of controls reflecting home and foreign demographic and economic variables (x_k and x_k^f, respectively),

$$k^f = K[\tau : \tau^f, x_k, x_k^f], \tag{2}$$
$$K_\tau[.] < 0,\ \ K_{\tau^f}[.] > 0.$$

This capital mobility function allows economic and demographic variables to affect home capital demand insofar as they impact production possibilities and the marginal product of capital. It proves convenient to assume that the derivatives with respect to the home and foreign capital tax rates are equal and opposite in sign ($K_\tau[.] = -K_{\tau^f}[.]$), though the qualitative results do not require this assumption.[6]

---

[5] If the state is a net capital exporter, $k^f < 0$. Without loss in generality, we analyze a capital importing state.

[6] While equation (2) and its partial derivatives are consistent with the implications from the standard constraint equating net-of-tax returns across jurisdictions, our formulation allows for the possibility that, owing to a variety of frictions (discussed in the literature on the Lucas Paradox (Lucas, 1980)), the net-of-

Equations (1) and (2) can be combined to generate a relation between production and the home and foreign tax rates,

$$y = F[K] = F\left[K[\tau:\tau^f, x_k, x_k^f]\right] = G\left[\tau:\tau^f, x_k, x_k^f\right], \tag{3}$$

$$G_\tau[.] < 0, \;\; G_{\tau^f}[.] > 0.$$

The derivative, $G_{\tau^f}[.] > 0$, represents the incremental home production from a tax-induced flow of capital from the foreign state to the home state.

Third, we link net income to expenditures by means of GDP accounting relations. Net income available for domestic expenditures is measured by gross income (production) less the return on capital assets (r^f) owned by foreign residents but located in the home state. Net income is set equal to domestic expenditures, defined as the sum of private goods (c) and public goods (g),

$$y - r^f = c + g. \tag{4}$$

Fourth, the government budget constraint (stated per unit of the fixed factor) equates public goods expenditure to two sources of tax revenue. For the purposes of this study, the most important tax is an origin-based tax on capital income. This tax is defined as the product of the capital income tax rate (τ) and capital income, the latter defined as the marginal product of capital ($F'[K]$) multiplied by the capital stock located in the home state. The second source of revenue is a value-added sales tax defined as the product of the sales tax rate (s) and income. This tax rate will be held constant in this analysis. The government budget constraint becomes,

$$g = \tau \; F'[K]\, K + s\, y = \tau\, \pi\, y + s\, y = (\tau\, \pi + s)\, y.^{7} \tag{5}$$

Given the Cobb-Douglas production function, capital income in the home state is a fixed share (π) of output.

---

tax returns on capital may differ. See Appendix B for analytic details about the capital mobility function.

[7] A wage tax at rate τ_{wage} could enter the model by adding ($\tau_{wage}(1-\pi)$ y) to the right side of equation (5).

Fifth, capital imported from abroad is paid a return equal to the marginal product of capital multiplied by the amount of foreign capital located in the home state. As a result of the Cobb-Douglas production function, the return on imported capital is a fixed share (π^f) of output,

$$r^f = F'[K]\,k^f = \pi^f y, \qquad (6)$$
$$\pi^f < \pi.$$

Equations (4), (5), and (6) can be combined to generate a relation between the mix of private to public goods ($c/g \equiv \zeta$) and the capital tax rate. We multiply and divide the two terms on the right-side of equation (4) by g, use equations (5) and (6) to eliminate g and r^f, respectively, and rearrange the resulting equation to obtain the following equation,

$$c/g \equiv \zeta = \left(1-\pi^f\right)\Big/\left(\tau\pi+s\right) - 1 \equiv H[\tau], \qquad (7)$$
$$H_\tau[.] < 0.$$

This condition shows that an increase in the share of output devoted to public goods requires an increase in the capital tax rate.

The sixth and final equation is the utility function that represents preferences for private and public goods and that policymakers maximize by their choice of τ. In the tax competition literature, the standard approach for representing preferences specifies a direct utility function with c and g as arguments and a set of constraints (equations (3) and (7) in the current framework). This approach can be followed in this model to determine the optimal τ (τ^*). A specific example is provided in Appendix C and, while it yields an explicit solution for τ^*, this solution is not fully informative for the purposes of this study. Instead, we work with an indirect utility function corresponding to the direct utility function in terms of c and g. Sufficient conditions linking these primal and dual representations are positive prices, local non-satiation in c and g, and strictly convex preferences; these conditions also ensure uniqueness (Kreps, 1990, Propositions 2.13 and 2.14, pp. 45-48).

We represent the utility of the representative home resident by the addilog utility function. Houthakker (1960) introduced this function and noted that it is most suitable when the arguments in the utility function are large distinct aggregates and when the primary force driving allocations is through changes in income. Both properties are satisfied in our tax competition setting, and we work with the following indirect utility function ($V[y]$),

$$V[y] = \xi_c \left(y(1-\pi^f)/p_c\right)^{\theta_c} + \xi_g \left(y(1-\pi^f)/p_g\right)^{\theta_g}, \tag{8}$$

where $\theta_c, \theta_g, \xi_c$, and ξ_g are positive parameters representing state-specific characteristics such as political preferences and p_c and p_g are the prices for c and g, respectively. A key property of the addilog indirect utility function is that "ratios between any two expenditures have a constant elasticity with respect to total expenditure" (Houthakker, 1960, p. 253). Relying on Roy's identity to generate the demand functions for c and g, we obtain after some additional manipulation the following equation for the ratio of the demands for c to g (Houthakker, 1960, equation (30)),

$$c/g \equiv \zeta = \zeta[y(1-\pi^f) : x_\zeta] = \xi\left(y(1-\pi^f)\right)^{\eta_{\zeta,y}}, \tag{9}$$

$$\xi \equiv \left(\xi_c\theta_c / \xi_g\theta_g\right)\left(p_c^{-(\theta_c+1)} / p_g^{-(\theta_g+1)}\right) > 0,$$

$$\eta_{\zeta,y} \equiv \theta_c - \theta_g >=< 0.$$

In equation (9), the private/public goods mix depends on income, home state control variables (e.g., population and voter preferences) represented by x_ζ, and prices (through ξ). A preference between private and public goods is a key element in this and other tax competition models.[8] In equation (9), this preference is represented by the θ_c and θ_g parameters whose difference defines the income elasticity of private goods relative to public goods, $\eta_{\zeta,y}$. This elasticity plays a major role in determining the sign of the slope of the reaction function and is tied closely to political preferences. If the representative person in a state is fiscally conservative, that state would likely have an $\eta_{\zeta,y} > 0$, while a state with a liberal fiscal agenda would likely have $\eta_{\zeta,y} < 0$.

The above model serves as a vehicle for studying the properties of the tax reaction

[8] See Keen and Konrad (2013) for a recent survey and the studies listed in fn. 11 for specific examples.

function. The model is summarized by equations (3), (7), and (9). Substituting the first two equations into the third equation, we determine the optimal capital tax rate, τ^*, and its relation to the foreign capital tax rate,

$$
\begin{aligned}
c/g &= \zeta[y(1-\pi^f) : x_\zeta], && (10)\\
0 &= \zeta\left[G[\tau^* : \tau^f, x_k, x_k^f](1-\pi^f) : x_\zeta\right] - H[\tau],\\
0 &= \Phi[\tau^* : \tau^f, x].\\
& \qquad x \equiv \{x_k, x_k^f, x_\zeta, \pi^f, \pi, s\}
\end{aligned}
$$

Appendix D verifies the existence of τ^*.

B. Empirical Implications

Equation (10) implicitly defines a relation between home and foreign capital tax rates, and thus can be used to compute the reaction function for τ^* with respect to changes in τ^f. Adopting the standard Nash assumption used in the literature, we assume policymakers in the home state treat foreign tax policy as given. Differentiating equation (10) with respect to τ^* and τ^f with the chain rule and rearranging yields the following reaction function,

$$
\frac{d\tau^*}{d\tau^f} = \frac{\eta_{\zeta,y}\,\Gamma}{\left(\eta_{\zeta,y}\Gamma - \left((\tau\pi)/(\zeta(\tau\pi+s)^2)\right)\right)}, \tag{11a}
$$

$$
\Gamma \equiv \eta_{y,K}\cdot(-\eta_{K,\tau}) \geq 0, \tag{11b}
$$

where the η's are elasticities and $\eta_{y,K}$ and $-\eta_{K,\tau}$ are positive. These two parameters are represented by Γ, defined in equation (11b) and interpreted as the change in output from a tax-induced flow of capital.

The first empirical implication of our model follows from the relation between the slope of the reaction function and $\eta_{\zeta,y}$ (the income elasticity of private goods relative to public goods) and is evaluated when this parameter is zero, negative, or positive. To develop the intuition for the slope of the reaction function under alternative values of $\eta_{\zeta,y}$, consider the situation where the foreign capital tax rate (τ^f) rises. Mobile capital (eventually) flows into the home state (because $K_{\tau^f}[.] > 0$), and thus the tax base (capital income, πy) rises (because $G_{\tau^f}[.] > 0$).[9] The allocation of this "windfall" income to private vs. public goods and the subsequent impact on financing of public goods through taxation are the key elements determining the sign of the slope of the reaction function, as we will see in the subsequent three cases.

Case I: $\eta_{\zeta,y} = 0 \;\rightarrow\; d\tau^*/d\tau^f = 0$

The assumption that the relative division of resources between private and public goods remains unaltered ($\eta_{\zeta,y} = 0$) implies that there is no need to change the home tax rate to alter the mix. This case is consistent with homothetic utility in private and public goods. The reaction function is flat.

Case II: $\eta_{\zeta,y} < 0 \;\rightarrow\; d\tau^*/d\tau^f > 0$

Under this assumption, the one term in the numerator and the two terms in the denominator of equation (11) are each negative; hence the overall derivative is positive. The negative value for $\eta_{\zeta,y}$ represents a preference for diverting a disproportionate amount of the windfall toward the public good. Since public goods need to be financed by tax revenues, this preference dictates an increase in τ^* and thus a positive-sloping reaction function.

Case III: $\eta_{\zeta,y} > 0 \;\rightarrow\; d\tau^*/d\tau^f < 0$

Under this assumption, the numerator is unambiguously positive; the slope of the reaction function depends on the relative magnitudes of elasticities in the denominator. Based on conventional parameter values, a sufficient condition for the denominator to be negative is $0 < \eta_{\zeta,y} < 3.0$.[10] Under this condition, the windfall is directed toward a relative increase in

---

[9] An additional benefit from the relatively lower tax rate (not modeled here) is that, if firms in the home state are non-competitive, the capital inflow increases production and competitive pressures, possibly lowers non-competitive profit margins, and increases welfare. This channel has been documented in the context of offshore financial centers by Rose and Spiegel (2007).

[10] This sufficient condition is based on the following computation. The two elasticities defining Γ ($-\eta_{K,\tau}$ and $\eta_{y,K}$) are 1.00 and 0.33 (capital's share in production), respectively. The remaining parameters are estimated from NIPA data as averages for the period 2000-2009: $\zeta = 3.701$, $\tau\pi = 0.003$, $s = 0.025$. (See the note to Figure 5 for details.) If, $\eta_{\zeta,y} < 3.0$, then

private goods. For instance, residents may view current levels of public services as satisfactory and would thus rather spend most or the entire windfall on private consumption. The windfall relaxes the budget constraint and allows the home state to lower tax rates while maintaining public good consumption. Such a situation would result in a negative or "see-saw" tax reaction.[11]

The above analysis highlights that the slope of the reaction function is indeterminate *a priori* and depends crucially on the income elasticity of private goods relative to public goods ($\eta_{\zeta,y}$). This sensitivity is documented in Figure 5, which plots the slope of the reaction function (equation (11)) against values of $\eta_{\zeta,y}$ ranging from -1.5 to +1.5 in increments of 0.10. As noted above, the appropriate value for $\eta_{\zeta,y}$ is related to the validity or invalidity of Wagner's Law. Unfortunately, the literature has reached different conclusions, with the time series evidence tending to favor $\eta_{\zeta,y} < 0$ and the cross-section evidence finding that $\eta_{\zeta,y} > 0$ (Ram, 1987). Unfortunately, the empirical issue remains far from resolved.

The model developed in this Section has an additional testable implication – the slope should vary systematically depending on whether the tax instrument applies to highly mobile new capital or less mobile old capital.[12] Capital mobility is measured by the absolute value of the elasticity of capital with respect to the tax instrument, $-\eta_{K,\tau}$. Differentiating equation (11) with respect to this elasticity, we obtain the following result,

$$\frac{d\left(d\tau^* / d\tau^f\right)}{d(-\eta_{k,\tau})} = \left(\frac{-\eta_{\zeta,y} * \eta_{y,K} * \left((\tau\pi)/(\zeta(\tau\pi+s)^2\right)}{\left(\eta_{\zeta,y} * \Gamma - \left((\tau\pi)/(\zeta(\tau\pi+s)^2)\right)\right)^2} \right) \begin{pmatrix} = 0 & \text{if} & \eta_{\zeta,y} = 0 \\ > 0 & \text{if} & \eta_{\zeta,y} < 0 \\ < 0 & \text{if} & \eta_{\zeta,y} > 0 \end{pmatrix}. \tag{12}$$

$(\eta_{\zeta,y} * \Gamma) < 1.0$ and, since $(\tau\pi)/(\zeta(\tau\pi+s)^2 > 1.0$, the denominator of equation (11) is negative.

[11] The theoretical possibility of a negatively sloped reaction function has been emphasized by Bruecker and Savaadra (2001, section on "Reaction Functions") and de Mooji and Vrijburg (2012) and noted, though not usually highlighted, in several other tax competition studies: Mintz and Tulkens (1986, Section 3.2 and fn. 15), Wilson and Janeba (2005, p. 1218), and Zodrow and Mieszkowski (1986, Section III). Razin and Sadka (2011) show that a standard tax competition model augmented with an upward supply of immigrants does not lead to lower tax rates and a race to the bottom. Mendoza and Tesar (2005) establish that, in a model where government spending is held constant, the occurrence of a race to the bottom is sensitive to which tax instrument (labor vs. consumption tax rates) is used to balance the budget in the face of a decrease in the capital income tax rate.

[12] Wildasin (2007) makes an important point about the differential sensitivity of "new" and "old" capital to the ITC and CIT, respectively, and discusses the implications for tax policy and rent transfers.

This equation shows that the magnitude of the reaction function slope is affected by the interaction between capital mobility $(-\eta_{K,\tau})$ and $\eta_{\zeta,y}$. If $\eta_{\zeta,y} > 0$ (and the sufficient condition discussed above holds), the slope of the reaction function will be negative, and an increase in capital mobility will make the reaction function slope even more negative. Symmetrically, if $\eta_{\zeta,y} < 0$, the slope of the reaction function will be positive, and an increase in capital mobility will make the reaction function slope even more positive. Intuitively, the more responsive capital is to tax stimuli (i.e., the higher is $-\eta_{K,\tau}$), the larger the movements in the tax base resulting from home vs. foreign tax differential changes, and hence the greater the responsiveness of the home tax rate to changes in the foreign tax rate. These scenarios imply that a negatively sloped (positively sloped) reaction function will be more negative (more positive) for the tax instrument targeting relatively mobile capital. In the empirical work, we expect that the slope of the reaction function will be greater in absolute value for the investment tax credit affecting new capital versus the corporate income tax rate that affects both new and old capital:

$$\left|\frac{d\,ITC}{d\,ITC^{f}}\right| > \left|\frac{d\,CIT}{d\,CIT^{f}}\right| . \tag{13}$$

To summarize, the model developed in this section guides the specification of the econometric model and the interpretation of the empirical results. In this framework, the sign of the reaction function is ambiguous and depends on the sign of the income elasticity of private goods relative to public goods for the representative household. Moreover, the absolute value of this slope increases with capital mobility. The latter is measured by the tax-price elasticity for capital $(-\eta_{K,\tau})$, and this elasticity is higher for the investment tax credit rate (targeting new capital) than for the corporate income tax rate (targeting both new and old capital).

III. Estimation Issues

A. The Estimating Equation

The main objective of our empirical work is to identify the slope of the reaction function for state capital tax policies. We focus primarily on the investment tax credit rate (ITC) and the corporate income tax rate (CIT). As extensions to these results, we also estimate models for the other three tax variables displayed in Figures 3 and 4: the tax wedge of capital, the average corporate tax rate, and capital apportionment weight. The strategic tax competition model developed in Section II implies that the reaction function can be represented by a specification of the following form,

$$\tau_{i,t} = \alpha\tau^{f}_{i,t} + x_{i,t}\beta + u_{i,t}, \tag{14}$$

where $\tau_{i,t}$ is a tax variable for state *i* at time *t*, $\tau^{f}_{i,t}$ is the tax variable for the foreign states, $x_{i,t}$ is a vector of control variables, $u_{i,t}$ is an error term, and the scalar α and vector β are parameters to be estimated. We measure $\tau^{f}_{i,t}$ by the 1st order spatial lag of the tax variable, $\tau_{i,t}$,

$$\tau^{f}_{i,t} \equiv S^{1}\left\{\tau_{i,t}\right\} = \sum_{j\neq i}^{J}\omega_{i,j}\tau_{j,t}\ , \tag{15a}$$

$$\sum_{j\neq i}^{J}\omega_{i,j} = 1\,, \tag{15b}$$

where $S^{p}\{.\}$ is the spatial lag operator of order p, $\omega_{i,j}$ is a weight defining the "distance" between state *i* to the remaining *J-1* states indexed by *j*. Given the presence of a spatial lag of the dependent variable as an explanatory variable, equations of the above form are sometimes referred to as a spatial autoregressive models. An immediate implication of the strategic tax competition model is that $\tau^{f}_{i,t}$ will be endogenous; Section III.C addresses this endogeneity issue and discusses how we overcome the potential problem of inconsistent parameter estimates.

We include five variables in the vector $x_{i,t}$ (which contains variables dated t and t-1). Three control variables are chosen to account for preferences for the mix of private and public goods ($x^{pref}_{i,t-1}$) and for economic ($x^{eco}_{i,t-1}$) and demographic ($x^{dem}_{i,t}$) effects. To avoid estimation problems arising from simultaneity, the preference and the economic variables are time lagged one period. As suggested by the theoretical model, 1st order spatial lags of the economic and demographic control variables ($x^{eco,f}_{i,t-1}$ and $x^{dem,f}_{i,t}$, respectively) capture the impact of foreign variables on capital demand (equation (2) and ultimately the setting of tax rates (equation (10)).

We extend the basic specification used in the tax competition literature (equation (14)) in two important ways. First, we allow for the possibility that the impact of the key tax competition variable may be distributed over several time periods. The introduction of time lags of competitive states' tax policy, $\tau^{f}_{i,t-n}$, recognizes that the driving force behind a non-zero reaction function slope is the mobility of capital, which occurs gradually over several years. Appendix E derives a distributed lag econometric equation that captures this gradual response by combining a static tax reaction function with a partial adjustment model.

Second, our specification of the error term is new to the study of state tax policy (to the best of our knowledge) and has a generalized two-way error component structure that allows for heterogeneous cross-section dependence (CSD) among states,

$$u_{i,t} = \varphi_i + \gamma_i f_t + \varepsilon_{i,t}, \qquad (16)$$

where φ_i is a state-specific shock, $\varepsilon_{i,t}$ is a state-specific shock that varies over time and is independent of $x_{i,t}$, f_t is an unobserved time-specific shock (f_t may represent a vector of shocks), and γ_i is a state-specific aggregate factor loading. The $\gamma_i f_t$ term allows for heterogeneous CSD among the states that may be important. All states are affected by common aggregate shocks such as energy prices, federal and foreign tax policies, globalization pressures, and U.S. macroeconomic conditions. These aggregate shocks are represented by f_t. However, the impact (direction and magnitude) of these aggregate shocks may vary by state. For instance, changes in energy prices may have different effects on New England states than on those states involved in the production of oil (e.g., Oklahoma and Texas) or biofuels (e.g., Illinois and Iowa). These differential responses are captured by the state-specific factor loadings, γ_i. The conventional time fixed effects (TFE) model is a special case of this framework and is obtained from equation (16) when $\gamma_i = \gamma$ for all *i*.

These two considerations lead to the following specification of our estimating equation,

$$\tau_{i,t} = \alpha_0 \tau^f_{i,t} + \sum_{n=1}^{N} \alpha_n \tau^f_{i,t-n} + x_{i,t}\beta + \varphi_i + \gamma_i f_t + \varepsilon_{i,t} \ . \tag{17}$$

For convenience, we will denote the sum of the coefficients on the current and lagged values of the competitive states' tax variable, which represents the long-run slope of the reaction function, by α,

$$\alpha \equiv \sum_{n=0}^{N} \alpha_n \ . \tag{18}$$

The strategic tax competition model necessarily implies that the three shocks – φ_i, $\varepsilon_{i,t}$, and $\gamma_i f_t$ – that affect state *i* are correlated with tax policy in the competitive states, $\tau^f_{i,t}$. We address the resulting estimation problem in the following three ways. First, φ_i is modeled as a state fixed effect.[13] Second, $\gamma_i f_t$ is modeled using the Common Correlated Effects (CCE) estimator of Pesaran (2006) that will be discussed in Section III.B. Third, the correlation between $\varepsilon_{i,t}$ and $\tau^f_{i,t}$ is accounted for by projecting the latter variable on a set of instruments, $z_{i,t}$. Our implementation of the instrumental variables estimator is somewhat complicated by the CCE estimator, and we address this problem in Section III.C.

B. The Common Correlated Effects (CCE) Estimator

The CCE estimator is an important innovation for analyzing tax competition because it allows states to have heterogeneous responses to aggregate shocks. Such common shocks are usually controlled for in panel studies with time fixed effects. As discussed above with respect to energy prices and similar macroeconomic factors, the assumption that all states are affected identically by aggregate shocks is restrictive and may bias all estimated coefficients. Of particular concern is the possibility that states' responses to aggregate shocks are correlated across space in a similar manner to the spatial pattern of capital mobility and hence tax

[13] State fixed effects capture, among other channels of influence, the impact of state size on capital income tax rates (Haufler and Wooton, 1999).

competition. Heterogeneous responses could be accounted for by Seemingly Unrelated Regression, but this framework is not feasible when the number of cross-section units exceeds 10. The CCE estimator, on the other hand, is feasible for panels with a large number of cross-section units and it accounts for the unobservable $\gamma_i f_t$ by including cross-section averages (CSAs) of the dependent and independent variables as additional right-hand side variables,

$$\begin{aligned} \tau_{i,t} &= \alpha_0 \tau^f_{i,t} + \sum_{n=1}^{N} \alpha_n \tau^f_{i,t-n} + x_{i,t}\beta + \varphi_i + \varepsilon_{i,t} \\ &+ \gamma_i \left(\bar{\tau}_t - \alpha_0 \bar{\tau}^f_t - \sum_{n=1}^{N} \alpha_n \bar{\tau}^f_{t-n} - \bar{x}_t \beta \right), \end{aligned} \tag{19}$$

where the bar above a variables denotes its CSA. If the γ_i's in equation (19) are constrained to be 1 for all *i*, the specification would be equivalent to transforming the data by demeaning each variable with respect to its CSA, the standard way of controlling for time fixed effects with the least squares dummy variables (LSDV) estimator. In general, the CSAs in the CCE estimator are formed with a set of state weights, v_j for j = 1,…,J, (note that these weights are unrelated to the $\omega_{i,j}$ state-pair weights used to construct the tax competition variable in Section IV.C), such that,

$$\bar{x}_t \equiv \sum_{j=1}^{J} v_j x_{j,t}, \tag{20}$$

$$\sum_{j=1}^{J} v_j = 1.$$

As shown by Pesaran (2006), the asymptotic properties of the CCE estimator are invariant to the choice of the v_j weights. The empirical work reported here is based on equal weighting ($v_j = 1/J$ for all j).

C. Endogeneity and Instrumental Variables

The theory of tax competition has the strong implication that $\tau^f_{i,t}$ will be correlated with shocks to $\tau_{i,t}$ appearing in the error term. We address this endogeneity problem with instrumental variables (IV).[14] The endogenous $\tau^f_{i,t}$ variable is projected on a set of instruments $z_{j,t}$. The fitted value, $\hat{\tau}^f_{i,t}$, then replaces $\tau^f_{i,t}$ in equation (19).[15]

A common challenge in the empirical tax competition literature is to identify a set of appropriate instruments from the very large pool of potential instruments. Tax competition theory, as well as spatial-econometric analysis (e.g., Kapoor, Kelejian, and Prucha, 2007), typically suggest that spatial lags of the control variables should be appropriate instruments. Appropriate instruments consist of voter preference variables for the competitive states representing political outcomes for the executive and legislative branches. The political party affiliations of and interactions among the governor and state legislators should provide good proxies for preferences (Besley and Case (2003); Snyder and Groseclose (2000); Reed (2006)). These variables should be highly correlated with the foreign tax variable and uncorrelated with shocks to the home tax variable. The latter property might be compromised by national "political waves" (e.g., the Reagan Revolution) that affect all states more or less the same or by regional effects (e.g., similarities among Southern states). These potential correlations are captured and neutralized by the time and state fixed effects, respectively. Thus, in effect, we instrument for changes in tax rates in competitive states using changes in the political party affiliations in those states, while conditioning on changes in political party affiliations in the home state. Changes in foreign states' political party control, holding fixed the home state's party control and state and time fixed effects, will be valid instruments so long as home state policymakers do not change

[14] Instrumental variables is one of two approaches typically used to estimate spatially autoregressive models. The other is maximum likelihood (e.g., Case, Hines, and Rosen, 1993), which is far more computationally intensive. See Brueckner (2003) for an extensive discussion of the econometric issues associated with identification of spatially autoregressive models in the context of tax competition and Pesaran (2006, Section 1) for a general review of estimation strategies.

[15] Since $\hat{\tau}^f_{i,t}$ is a generated regressor, we have investigated whether adjusting the standard errors with the procedure of Topel and Murphy (1985) has a notable impact on the standard errors. The adjustment turns out to have very little impact and hence we do not include this adjustment in the results shown in this paper. Moreover, for testing the null hypothesis that the coefficient on $\hat{\tau}^f_{i,t}$ equals zero, no adjustment is necessary (Pagan, 1984).

home tax policy in direct response to changes in political party control in other states.

The potential set of instruments for a given tax variable indexed by τ for state *i* at time *t*– $Z_{\tau,i,t}$ – is constructed from spatial lags of the conditioning variables.[16] We consider 1st and 2nd order spatial lags of the eight voter preference variables defined in Section IV.D. This procedure generates a $Z_{\tau,i,t} = \left\{ z^{1}_{\tau,i,t}, \ldots, z^{16}_{\tau,i,t} \right\}$ containing 16 candidate instruments. Unfortunately, IV estimators are known to be biased in finite samples when a large number of instruments are used (Hansen, Hausman, and Newey, 2008).

To avoid this bias, we adopt the following search procedure to obtain an optimal instrument set for each of our tax variables.[17] We form candidate instrument sets corresponding to all possible combinations of 1st order and 2nd order spatial lags of the voter preference variables, with the restriction that, if a candidate set contains the 2nd order spatial lag, the corresponding 1st order spatial lag must also be contained in the candidate set. Given that we consider eight preference variables, this procedure yields just over 1,000 candidate instrument sets. For each candidate set and for a given tax variable, we estimate the two-way fixed effects IV model and choose the instrument set that is valid (cf., fns. 17 and 19) and has the best first-stage fit, the latter determined by the minimum eigenvalue (Cragg-Donald) statistic.[18] For

[16] An interesting issue related to the proper choice of instruments for a panel model with two-way fixed effects is the potential "Nickell bias" (Nickell (1981)). As is well known in time-series models, the within IV estimator with predetermined variables (e.g., time lagged endogenous variables) is biased in finite-T samples because the predetermined variables are correlated with the within-transformed error term. In principle, this suggests that time lags of included instruments are invalid. However, what is not generally recognized is that there also is a parallel (or perhaps "perpendicular") finite-N bias coming from the spatial dimension. The two-way within estimator also transforms the error to sweep out time fixed effects that may be correlated with *spatial* lags of the included instruments, thus invalidating such spatial lags as instruments. It is important to keep in mind, however, that both biases vanish as T or N gets large and the rate of convergence is rather rapid. Thus, these potential problems do not arise in our dataset with T and N dimensions of 42 and 48, respectively.

[17] Ideally, we would select an optimal set of instruments with a procedure that allows us to assess instrument relevance and validity simultaneously. To the best of our knowledge, there are no such formal statistical tests for choosing instruments (or moment conditions). For example, the moment selection procedures of Andrews (1999) and Andrews and Biao (2001) focus on instrument validity and maintain instrument relevance, while instrument selection procedures such as Donald and Newey (2001) focus on relevance and assume validity. Absent such a procedure, we remove candidate instrument sets that are invalid, where the latter condition is assessed with Hansen's J-statistic evaluated at the 10% level.xx In our particular application, the absence of a procedure for assessing instrument relevance and validity simultaneously is not important, as our results are completely robust to dropping instrument validity restrictions (cf. fn. 19).

[18] Optimal instrument sets are identified separately for models without lags and with three lags of $\tau^{f}_{i,t}$

instance, for the model with CIT as the dependent variable and containing three lags of the tax competition variable, the instrument set yielding the highest first-stage fit turns out to consist of just two variables: the 1st order spatial lag of the interaction between governor party and legislature majority party and the 1st order spatial lag of whether an incumbent governor was reelected last year. For the model with ITC as the dependent variable and also containing three lags of the tax competition variable, the chosen instrument set is similar: the 1st order spatial lag of the legislature majority party and the 1st order spatial lag of whether an incumbent governor was reelected last year.[19] While we are not interested here in formal hypothesis testing of instrument relevance, it is interesting to evaluate the null hypothesis of instrument irrelevance in terms of the 5% critical values presented in Table 1 of Stock and Yogo (2005); for seven or fewer excluded instruments and a bias greater than 10%, the critical value is 11.29. The instrument sets selected by our algorithm (one each for the five tax policies we analyze) all exceed this critical value. The optimal instrument set thus identified for a given tax variable is labeled $z^*_{\tau,i,t}$.

D. The General Specification and Implementation

The above considerations lead to the following general specification that is the basis of the estimates reported in Section V,

$$
\begin{aligned}
\tau_{i,t} &= \alpha_0 \hat{\tau}^f_{i,t} + \sum_{n=1}^{N} \alpha_n \tau^f_{i,t-n} + x_{i,t}\beta + \varphi_i + \varepsilon_{i,t} \\
&\quad + \gamma_i \left(\bar{\tau}_t - \alpha_0 \bar{\hat{\tau}}^f_t - \sum_{n=1}^{N} \alpha_n \bar{\tau}^f_{t-n} - \bar{x}_t \beta \right),
\end{aligned}
\tag{21}
$$

where, relative to equation (19), we have replaced the endogenous variable, $\tau^f_{i,t}$, with the fitted

The optimal instrument set obtained for the three-lag model is used for all models containing lags of $\tau^f_{i,t}$.

[19] When CIT is the dependent variable, the Hansen J-test validity screen does not bind, meaning that the instrument set with the highest first-stage fit generates a Hansen overidentifying restrictions J-test statistic less than critical values at conventional levels of significance. For the ITC, there are a small number of instrument sets yielding higher first-stage fits but not satisfying the overidentifying restrictions screen. The empirical results for the reaction function are robust to using these alternative instrument sets. Indeed, out of 1003 candidate instrument sets for the ITC model, 95.2% yield a negative and statistically significant α; none yields a positive and statistically significant α.

value, $\hat{\tau}^{f}_{i,t}$, in the first line and replaced the endogenous variable's CSA, $\bar{\tau}^{f}_{t}$, with the instrumental variable's CSA, $\bar{\hat{\tau}}^{f}_{t}$. When responses to aggregate shocks are constrained to be the same for all states, $\gamma_i = \gamma$, and this constrained estimator is equivalent to standard time fixed effects. For the purposes of comparison to prior studies, we also will present estimates that do not control for aggregate shocks; in this case, $\gamma_i = 0$.

The CCE model is nonlinear in parameters (cf., equation (21)), which complicates its implementation. There are at least three ways to estimate this model. The first approach ignores the nonlinear restrictions imposed on the model by simply allowing each of the CSA terms (the terms on the second line of equation (21)) to have a separate, state-varying coefficient. This can be implemented by interacting state dummies with each of the CSA terms and including all of these interactions, along with the other variables of the model (those in the first line of equation (21)), in a linear least-squares regression. For example, one would estimate a set of coefficients, $\theta_i = \gamma_i \alpha_0$, on the CSA of the contemporaneous tax competition variable, $\bar{\hat{\tau}}^{f}_{t}$. Such a regression is perfectly feasible, but it is quite inefficient given that it involves estimating a very large number of nuisance parameters. In our case, with 48 states, 5 control variables, and contemporaneous plus up to 4 lags of $\hat{\tau}^{f}_{i,t}$, we would have 586 parameters. We will refer to this estimator as the "unrestricted/inefficient CCE" estimator.

A second possible way of estimating this model is via a nonlinear estimator such as nonlinear least squares or maximum likelihood. However, even with the restrictions imposed, there are still a fairly large number of parameters to estimate, and nonlinear estimators may have difficulty converging.

A third approach, and our preferred one, is to first obtain consistent estimates of γ_i, insert these $\hat{\gamma}_i$'s into equation (21), and then estimate the resulting parsimonious model via linear least squares. Specifically, we implement the following three-step procedure (Appendix F presents a more formal treatment of this procedure):

- Step 1: Estimate the linear, unrestricted CCE estimator (with the γ_i's set equal to 1.0) to obtain consistent (but inefficient) estimates of α_0, α_n's, and β. (Number of estimated parameters = 586.)
- Step 2: Use these as initial values for the α_0, α_n's, and β that pre-multiply the CSA terms (i.e., those on the second line of equation (21)). Obtain new estimates of the α_0, α_n's, and β from the main regressors (i.e., those on the first line of equation (21)) and use them as the α_0, α_n's, and β on the second line (the γ_i's are also estimated at each iteration). Iterate until α_0, α_n's, and β in 1st and 2nd lines converge (the convergence criterion is that each individual parameter estimate is within 1% in absolute value of its previous value). At this point, the model yields consistent and efficient estimates of γ_i. (Number of estimated parameters = 106.)
- Step 3: Impose the $\hat{\gamma}_i$ from step 2. Estimate the resulting linear model via least squares to obtain consistent and efficient estimates of α_0, α_n's, and β (plus state fixed effects). (Number of estimated parameters = 58.)

We refer to this three-step estimator as the "efficient" or "restricted" CCE estimator. It should be emphasized that the purpose of imposing the CCE restrictions is for efficiency. Consistent estimates can also be obtained from the "unrestricted/inefficient" estimator in step 1. Thus, while most of the results we report below are obtained with the efficient CCE estimator, we also compare these results to those from the inefficient CCE estimator (see Table 4). As expected, the point estimates are similar between the two, but the efficient estimates are much more precise.

IV. U.S. State-Level Panel Data

Our estimates of the capital-tax reaction function are based on a U.S. state-level panel data for the period 1965 to 2006. We stop at 2006 to avoid the effects of the financial crisis and the Great Recession. The panel aspect of these data is crucial for understanding state tax policy for at least three reasons. First, state-specific fixed factors, such as natural amenities, affect a state's desire for government services and hence its tax and expenditure policies. Initial policies, stemming perhaps from historical policy choices persisting to the present era due to political economy forces (Coate and Morris, 1999)) also determine current policies. The impact of these and other state-specific fixed factors (e.g., state industry mix) will be accounted for with state fixed effects. Second, state tax policy may be sensitive to aggregate shocks (e.g., energy prices) that vary over time, and these influences will be captured by time fixed effects or, more generally, by the CCE estimator that allows heterogeneous responses across states. Third, panel data long in the time dimension allow for the possibility that the response of state tax policy is distributed over several years. As we shall see in Section V, the latter two factors prove very important in the empirical analysis. We now turn to a discussion of the data underlying the variables used in our empirical analysis. Details about variable definitions and data sources are provided in Appendix A.

A. Capital Tax Policy (τ)

The model developed above, as well as the tax competition literature in general, analyzes the determination of a single tax on each unit of capital. Across the 48 states, the primary capital-tax policies are investment tax credits (ITC) and the corporate income tax (CIT). These policies target different types of capital, and hence their reaction functions should have different slopes that depend on the degree of mobility of the targeted capital. The reaction functions associated with these two tax variables form our baseline empirical results presented in Section V.A. We extend our analysis by estimating the reaction functions associated with three other tax variables – the tax wedge on capital, the average corporate tax rate, and the capital apportionment weight – in Section V.C.

B. Control Variables (x)

Recall that our model of strategic tax competition implies that variation in state capital tax policy is due, in part, to variation in demographic, economic, and political preference control variables that we measure by population (POPULATION), the investment/capital ratio (IK), and voter preferences (PREFERENCES), respectively. State population data come from the U.S. Census Bureau. We measure the investment/capital ratio using data for the manufacturing sector. The raw source data used to construct this variable is the Annual Survey of Manufacturers (ASM). The real manufacturing capital stocks are constructed according to the perpetual inventory method. Analogous state data outside of manufacturing for the years of our sample are unavailable.

Political preferences of state residents, while unobserved, should to a large extent be revealed by electoral outcomes. Specifically, we measure the following two political outcomes as indicator variables:

(a) the governor is Republican. (The complementary class of politicians is Democrat or Independent. An informal examination of the political landscape suggests that Independents tend to be more closely aligned with the Democratic Party. We thus treat Democrats and Independents as belonging to the same class);

(b) the majority of both houses of the legislature are Republican.

The PREFERENCES variable takes on one of three values:

0 if the governor and the majority of both houses of the legislature are not Republican;

1/2 if the governor is Republican but the majority of both houses of the legislature are not Republican or if the governor is not Republican but the majority of both houses of the legislature are Republican;

1 if the governor and the majority of both houses of the legislature are Republican.

C. Foreign (Out-of-State) Variables (τ^f, x^f)

The two-state model developed in Section II is useful for understanding the intuition of strategic tax competition, but its focus on a single foreign jurisdiction is obviously highly stylized. In taking a tax competition model to data, one must confront the issue of evaluating the model when there are many foreign states competing for the capital tax base. It is generally infeasible to allow for a separate slope of the tax reaction function for each and every other foreign state. The approach taken in the literature, which we follow in this paper, is to measure foreign state variables (denoted by a superscript *f*) using spatial lags of the home state variable. A spatial lag is a weighted average of a variable over all foreign states.

In this paper, we focus on tax competition among the 48 contiguous U.S. states.[20] Equation (15) details the construction of the spatial lag and the weighting matrix, *W*, a 48x48 matrix with elements $\omega_{i,j}$ defining the "relatedness" of state *i* to the remaining 47 states indexed by *j*. The elements of the weighting matrix are chosen *a priori* and are meant to capture the degree of potential mobility of capital between the i^{th} state to each of the *j* foreign states.

The most natural weighting scheme and the one used most frequently in the literature is based on geographic proximity. We construct a *W* matrix with elements equal to the inverse-distance between state pairs, where distance is the number of miles between each state's population centroid. Each row of *W* is normalized so that the elements sum to one. A shortcoming of this geographic proximity measure is that it may not sufficiently discriminate among states. For example, while one might suspect that the economic interactions between California and Texas are greater than between California and Nebraska, the geographic proximity measure will give approximately equal weight to both pairs of states. An extension presented in Section V.C constructs a matrix based on commodity trade-flows in which element $\omega_{i,j}$ is the (row-normalized) value of commodity shipments from the i^{th} state to the j^{th} state, according to data from the 1997 Survey of Commodity Flows.

D. Candidate Instruments (z)

As discussed in Section III.C, we rely on eight voter preference variables defined over foreign states to form the candidate sets of instruments. In addition to the two preference variables listed in Section IV.B for the governorship (a) and legislature (b), we consider the following six political variables:

(c) the majority of both houses of the legislature are Democrats or Independents;

(d) the governorship changed last year from a Republican to a Democrat or Independent;

(e) the majority control of the legislature changed last year from Democrat or split (between houses) to Republican;

(f) an interaction between the Republican governor and the Republican legislature indicator variables;

[20] We exclude Alaska, Hawaii, and the District of Columbia because of missing data for some of the weighting matrices and, for Alaska and Hawaii, because their great distance to other states strains the notion of "neighboring states."

(g) an interaction between Republican governor and the Democrat legislature indicator variables (note that the omitted interaction category is Republican governor and a split legislature dummy);

(h) the reelection of an incumbent governor last year.

Data for these political variables come from the Statistical Abstract of the United States (U.S. Census Bureau (Various Years)).

V. Empirical Results

A. Baseline Results

Tables 1 through 3 contain the core results of the paper. Standard errors are robust to heteroskedasticity and clustered by year. The purpose of clustering by year is to account for any remaining contemporaneous correlation of the error terms across states in a very general manner. In particular, the common assumption in spatial econometrics of 1st order spatial autocorrelation is subsumed within this general clustering.

Table 1 presents the results of estimating equation (21) for the investment tax credit (ITC) with cross-section dependence accounted for by the CCE estimator and with various time lags. Column A contains estimates for a static model (i.e., no time lags of $\tau^{f}_{i,t}$ are included) and, as has occurred frequently in the literature, the slope of the reaction function is positive and statistically significant at conventional levels. In fact, the point estimate is quite large. A reaction function slope outside the unit circle would be unstable, suggesting a lack of convergence to a steady-state equilibrium set of tax rates across states.

The sign of the reaction function, however, flips to negative when time lags of the tax competition variable are introduced. Column B adds the first time lag, $\tau^{f}_{i,t-1}$, to the specification. The sum of the two coefficients on $\tau^{f}_{i,t}$ and $\tau^{f}_{i,t-1}$ is now negative and statistically significant at the 1% level.[21] This sum of the contemporaneous and once-lagged tax competition variables, α,

[21] One interesting aspect of these results is that when lags are included, it is actually the contemporaneous value of $\tau^{f}_{i,t}$ that is found to have a negative coefficient while the time lags have positive coefficients. Taken literally, this implies that states react negatively to out-of-state tax changes in the first year and then backtrack to some extent in the following years. This result neither verifies nor rejects any aspect of

represents an estimate of the long-run slope of the reaction function. Adding additional lags of $\tau_{i,t}^{f}$ yields very similar long-run slope estimates, as shown in Columns C to E.

Table 2 repeats this exercise with the ITC replaced by the corporate income tax (CIT) rate. The qualitative pattern found for the ITC – a positive slope flipping to a negative slope when time lags are included – also holds for the CIT. However, for the CIT, the point estimates of the slope are closer to zero (relative to Table 1) for all of the specifications, and they are insignificantly different from zero for those specifications containing lags.

The estimated coefficients on the control variables in Tables 1 and 2 for the lagged models, which we believe to be the most appropriate specification, also warrant a brief discussion. The coefficient on PREFERENCES suggests that states where voters tend to vote Republican have lower values for the ITC and CIT. This result could be consistent with a "libertarian" or "tea party" type of Republicanism that favors both low investment subsidies and low corporate taxes and that recognizes that the former may need to be financed by the latter. The one-year-lagged investment rate ($IK_{i,t-1}$) has no significant effect on the ITC or CIT. The spatial lag of this variable ($IK_{i,t-1}^{f}$) has a negative and significant coefficient for ITC, perhaps suggesting that states view weak investment activity in competing states as an opportunity to attract capital to their own state by raising (or enacting) the ITC. Lastly, both home and foreign state populations negatively affect ITC and CIT rates.

Table 3 summarizes the variation in the estimated long-run slope of the reaction function, α, due to the tax policy instrument, the number of time lags included of the tax competition variable and controls for aggregate shocks. As discussed in Section III, the CCE estimator allows for heterogeneous responses to aggregate shocks across states, the time fixed effects (TFE) estimator allows only for homogeneous responses across states, and the estimator with no time fixed effects (NTFE, a one-way state fixed effects estimator) does not allow for any response to aggregate shocks.

Four key methodological findings emerge. First, the inclusion of time lags of the tax competition variable has a large and negative effect on the estimated slope of the reaction function. This finding holds regardless of whether and how one controls for aggregate shocks,

---

our model, which focuses on long-run equilibrium. It simply suggests that states may not move monotonically to the new equilibrium after a shock to out-of-state taxes and that a proper specification of the estimating equation needs to include time lags.

and it holds for both tax policies.

Second, controlling for at least one time lag, we find that the slope estimate is not very sensitive to the number of time lags included for our preferred CCE model. For ITC, the slope estimate varies between -0.58 and -0.69 and is always statistically significant. For CIT, the slope varies between 0.00 and -0.14, and in no case is statistically different from zero. For the remainder of the paper, we will treat the three-lag model as our preferred specification.

Third, controlling for aggregate shocks also has a strong effect on the estimated slope of the reaction function. For ITC specifications allowing for lagged responses, controlling for aggregate shocks with standard time fixed effects results in large negative slope estimates. Allowing for heterogeneous responses of states to aggregate shocks with the CCE estimator leads to more moderate and more plausible negative slope estimates for ITC. For CIT, adding standard time fixed effects has little impact on slope point estimates but increases standard errors substantially. However, allowing for heterogeneous responses to aggregate shocks with the CCE estimator has a strong effect on the slope estimate for CIT. The resulting CCE slope estimates for the CIT models with time lags are negative but close to zero.

Fourth, in unreported results, we find considerable variation in the estimated state-specific factor loadings on the aggregate shock, $\hat{\gamma}_i$. The null hypothesis of equality of the 48 $\hat{\gamma}_i$'s is easily rejected by a Wald test. The rejection of homogeneity suggests that the standard time fixed effects model is misspecified with respect to our data.

Aside from these methodological findings, the key economic result from Table 3 is that the slope of the reaction function for ITC is negative and significant, while the slope for CIT is insignificantly different from zero. Additionally, the larger (in absolute value) slope for ITC confirms the second implications of the theoretical model. As shown in equations (12) and (13), the absolute value of the slope of the reaction function is expected to increase with capital mobility. For the CCE model with three time lags, the estimated slopes are −0.588 and −0.077 for the ITC and CIT models, respectively; only the slope for the ITC is statistically different from zero. These results are consistent with our theoretical model and the targeting of less mobile (new and old) capital by the CIT and more mobile (only new) capital by the ITC.

As a check on the plausibility of these econometric results, we can calibrate our theoretical model to the estimated reaction functions and the assumed parameter values used in constructing Figure 5. For the ITC, the estimated slope of about -0.60 implies an income elasticity of private to public goods ($\eta_{\zeta,y}$) of about 1.20. The only difference between the CIT and ITC is the value of the elasticity of capital to the tax instrument ($-\eta_{K,\tau}$, cf. equation (12)). With $\eta_{\zeta,y} = 1.20$, the estimated slope for the CIT of about -0.10 implies a value for $-\eta_{K,\tau}$ of about 0.20, five times lower than the comparable value for the ITC.

In sum, our baseline results document that, when we account for time lags and aggregate shocks, the slope of the reaction function is negative. Allowing for both time lags in the tax competition variable and responses to aggregate shocks is crucial for obtaining an accurate estimate of the slope of the tax policy reaction function. Misspecifying the empirical model by failing to account for time lags or aggregate shocks leads to a positive slope estimates. Allowing for time lags is important because capital mobility among states is not instantaneous and occurs over more than one year. Allowing for aggregate shocks is important because they create common incentives that will lead states to act more-or-less synchronously. The positive slopes obtained when aggregate shocks are ignored accord with anecdotal evidence of positive reactions among states and the data in Figure 1. However, in order to properly assess the response of home state tax policy to foreign state tax policy, we must condition on aggregate shocks. With proper conditioning, the estimated slope of the reaction function is negative and more responsive for the ITC that targets new capital relative to the CIT that targets both new and old capital.

B. Robustness

In this subsection, we assess the robustness of our slope estimates to a variety of factors: (1) our method of implementing the CCE estimator; (2) the expansion of time lags to include all right-hand side variables, rather than just time lags of the tax competition variable; (3) the use of an alternative weighting matrix; (4) the modeling of dynamics with a lagged dependent variable; (5) the role played by additional tax variables in the reaction function.

Our first robustness check evaluates whether our three-step restricted CCE estimator yields similar results to the simpler unrestricted CCE estimator described in Section III.D. Both estimators are consistent, but the latter is relatively less efficient. The results for α, the estimated long-run slope of the reaction function, from each estimator, for specifications with varying lag lengths, are shown in Table 4. For our preferred specification with three time lags, the two estimators yield very similar slope coefficients for ITC and CIT. However, as expected, the standard errors from the linear unrestricted CCE estimator are much larger.

Our second robustness check assesses the sensitivity of our main results to including time lags of all independent variables as opposed to just the tax competition variable. Our preferred specification omits these additional time lags to conserve degrees of freedom, as each extra right-hand side variable introduces another CSA term in the CCE estimator. Nonetheless, estimating this full specification is feasible with CCE, as well as the standard two-way and one-way fixed effects estimators. The results are shown in Table 5. Relative to the results reported in Table 3, the same qualitative patterns emerge across estimators and across the number of lags in these "full" specifications, though the standard errors are larger, as expected. The only notable difference is that the CIT reaction function slope from the CCE estimator with four lags is large and statistically significant. This instability in results in Table 5 moving from one, two, or three lags to four lags suggests that degrees of freedom are being exhausted.

Our third robustness check investigates whether our baseline results are sensitive to our definition of the foreign state tax policy by repeating our main regressions using an alternative weighting matrix (cf. equation (15)) to form the foreign state tax variable, $\tau^{f}_{i,t}$. How states react to tax policy changes in other states most likely depends on exactly what other states are considered to be competing for the same mobile capital tax base. In all of the above results, $\tau^{f}_{i,t}$ was constructed as a weighted average of other states' tax policies using geographic proximity weights (the inverse of the distance between population centroids). However, state capital tax policy may be more sensitive to policies of states that are "economically close" rather than "geographically close." To measure economic closeness, we define the weighting matrix based on commodity trade flows; that is, state *j*'s weight in state *i*'s tax competition variable is proportional to the value of commodity shipments from state *i* to state *j*. Note that we only have data for one year, so this alternative weighting matrix could have considerable measurement error. The results discussed here are based on the three-lag specification and the efficient CCE estimator. For the ITC, the slope coefficient falls (in absolute value) from -0.588 (s.e. = 0.170) for the baseline results in Table 3 to -0.357 (s.e. = 0.081) but remains statistically significant. A negative slope is also obtained for CIT, as the coefficient estimate rises in absolute value from -0.077 (s.e. = 0.192) to -0.428 (s.e. = 0.172); the latter estimate based on trade flow weights is statistically significant at conventional levels. Thus, the baseline results of a negative and significant slope for the ITC reaction function and a non-positive slope for the CIT reaction function are robust to this alternative definition of state interrelatedness, however whether the CIT reaction slope is less steep than that of the ITC does depend on the nature of state interrelatedness.

Our fourth robustness check examines an alternative specification that captures dynamics with a lagged dependent variable (LDV). However, a major drawback of a dynamic model that includes one LDV and no lags of the independent variables is that the sign of the long-run effect on a given independent variable is restricted to be the same as the sign of the short-run effect. This restriction emerges because the long-run effect is calculated as the coefficient on the independent variable divided by one minus the coefficient on the LDV, which is typically between 0 and 1.[22] The LDV model is nested within the preferred model described above when the latter has an infinite number of lags (see Appendix G).[23] Of course, an infinite-lag model cannot be estimated, but a restricted version, in which the coefficients on the independent variables for the first N time lags are unrestricted and the effects of lags beyond the $N+1$ period are captured parsimoniously by the dependent variable lagged $N+1$ periods, can be estimated. (A complete set of results for this specification are available from the authors upon request.) For our preferred specification (N = 3), the coefficients on the dependent variable lagged four periods are 0.313 and 0.424 for the ITC and CIT models, respectively, and are statistically far from zero. Estimates of the α's are consistent with our key empirical results -- the implied long-run slope for the ITC remains negative and statistically significant (though with a larger point estimate of -0.973) and the implied long-run slope for the CIT remains negative and insignificant (with a point estimate of -0.172).

Our fifth and final robustness check explores the sensitivity of the empirical results to controlling for other home state tax policies. All of the empirical work reported so far examines how states vary a given capital tax policy in response to changes in that same capital tax policy in competing states. This focus on a single tax policy at a time is consistent with the approach taken in the literature, but there is the possibility that a change in the foreign capital income tax rate might result in changes in several taxes simultaneously. Incorporating multiple tax instruments into a coherent theoretical model has, to the best of our knowledge, not been achieved in the literature and is beyond the scope of the current study.

Nonetheless, it may be informative to consider empirically whether a given capital tax policy's estimated reaction slope changes if we hold other tax policies constant. This result

[22] This restriction can be seen by considering the formula for the long-run effect of a given variable in a lagged dependent variable model. The coefficient on any independent variable, call it α_0, represents the short-run effect of that variable. The long-run effect is given by $\alpha_0 / (1-\rho)$, where ρ is the coefficient on the lagged dependent variable and should be between 0.0 and 1.0. Thus, the long-run effect will always have the same sign as the short-run effect in a model that captures dynamics only with a lagged dependent variable. See Appendix G for further discussion.

[23] The use of an LDV also creates some econometric difficulties with correlations between the LDV and the state fixed effect (the "Nickell bias;" Nickell (1981), Devereux, Lockwood, and Redoano (2007)) and the LDV and a serially correlated error term (Jacobs, Ligthart, and Vrijburg, 2010).

seems unlikely for two reasons. First, correlations among the major state tax policies – ITC, CIT, and the individual marginal tax rate for a taxpayer earning the median income (PERS) – are quite low. Net of state and time fixed effects, the ITC/CIT, ITC/PERS, and CIT/PERS correlations are 0.08, 0.16, and -0.05, respectively. Second, as shown at the beginning of this subsection, when capital tax policy is measured comprehensively with the tax wedge on capital (TWC), the slope of the reaction function continues to be negative.

Despite this a priori evidence, we directly examine the extent to which our estimated reaction function slopes change if we explicitly hold other key tax policies fixed. We repeat the estimation of our preferred baseline models (using the CCE estimator and including 3 lags of $\tau^{f}_{i,t}$, as in column (3) of Tables 1, 2, and 6.A) with $\tau_{i,t}$ equal to either ITC, CIT, or TWC. Data on PERS is only available after 1976, so first we reestimate the baseline models for the post-1976 sample. The results are similar to those based on the full sample; the tax reaction slopes are -0.648 (standard error of 0.257) for ITC, -0.205 (0.167) for CIT, and -0.781 (0.236) for TWC. We then condition on the complementary class of tax variables (which we label Q). If these additional tax variables provide quantitatively important channels through which a state reacts to a foreign states capital tax policies, we would expect their introduction to substantially alter the slope of the estimated reaction function. We consider three models: (1) $\tau_{i,t} = ITC_{i,t}$, $Q_{i,t} = \left\{CIT_{i,t}, PERS_{i,t}\right\}$; (2) $\tau_{i,t} = CIT_{i,t}$, $Q_{i,t} = \left\{ITC_{i,t}, PERS_{i,t}\right\}$; and (3) $\tau_{i,t} = TW_{i,t}$ and $Q_{i,t} = \left\{PERS_{i,t}\right\}$. For models (1), (2), and (3), we find tax reaction function slopes of -0.735 (0.260), -0.241 (0.145), and -0.654 (0.234), respectively. It is clear, therefore, that reaction function slopes of capital tax policies are little affected by controlling for any influence foreign tax policies might have on other home state tax policies.

C. Extensions

This subsection extends the core analysis by considering three additional measures of capital taxation. The first additional measure of capital tax policy we consider is the tax wedge on capital (TWC). All of the above analyses have measured $\tau_{i,t}$ using one of two statutory tax policies, the investment tax credit rate or the corporate income tax rate. The TWC allows us to examine their combined effects by focusing on that part of the user cost of capital that incorporates both of these policies (see fn. 1 and Appendix A for details). Estimates of the benchmark model but using TWC as the tax variable are presented in panel A of Table 6. While point estimates are generally larger than in Table 3, the key patterns that we observed previously remain with TWC: models without aggregate effects or time lags of $\tau^f_{i,t}$ generate positive α's and the introduction of aggregate effects and time lags generates negative α's that are statistically different from zero at conventional levels.

The second additional tax policy measure is the average corporate tax rate ($ACT_{i,t}$). As we argue in more detail in Section VI below, statutory policies are the appropriate variables of interest in tax competition because they are the tax instruments that policymakers control directly. The average corporate tax rate, on the other hand, measures total state corporate tax revenues divided by a tax base and are largely beyond the control of policymakers. Though policymakers' choices regarding statutory policies influence this average rate, current economic conditions and other exogenous factors, especially the firm's choice of organization form, also have substantial effects.[24] Nonetheless, because average tax rate measures are often used in the empirical tax competition literature, we present results in panel B of Table 6 based a measure of $ACT_{i,t}$ in order to draw comparisons with some of the previous literature. The $ACT_{i,t}$ is the ratio of state corporate tax revenues to total state business income, the latter measured by gross operating surplus.

The $ACT_{i,t}$ results are mixed relative to the estimates based on statutory tax rates. Focusing on the CCE results, we find that the estimated slope of the reaction function based on the $ACT_{i,t}$ is positive in a static model. Many prior studies have been based on average tax variables in static models, and the results in Table 6 may partly explain why positively sloped reaction functions have been found previously. As with the benchmark model, the addition of one or two lagged values of $\tau^f_{i,t}$ yields negative slopes. However, the results are fragile; the addition of a third or fourth lag leads to a sign reversal and much larger estimated slopes. These results suggest that there can be a great deal of difference in estimated reaction function slopes when tax policy is measured by marginal and average tax rates, a finding consistent with the evaluation of statutory and average tax rates by Plesko (2003).

The third and final tax policy measure concerns another important, but less well-known, capital tax policy used by U.S. states, the Capital Apportionment Weight. The CAW is the weight that a state assigns to capital (property) in its formula for allocating a portion of a

[24] Regarding the sensitivity of organization form to corporate taxation, see Goolsbee (2004), Mackie-Mason and Gordon (1997), and Mooij and Nicodème (2008) for evidence across U.S. states, U.S. industries, and EU firms, respectively.

corporation's national income to that state and, per Figure 4, has fallen sharply over our sample period.[25] Unlike the ITC and CIT, changes in the CAW are somewhat difficult to interpret because an increase in the capital weight necessarily implies a decrease in the weights for the non-capital components in the apportionment formula; the net effect on incentives depends on the relative importance of capital and non-capital factors. With this caveat, the results for the capital apportionment weight are shown in Panel C of Table 6. Again, the introduction of time lags of the tax competition variable, combined with controlling for aggregate shocks, results in a sign flip of the long-run reaction function slope from positive to negative. The absolute values of the slope point estimates for CAW are much larger than those for ITC or CIT. These results strongly suggest that the slope of the reaction function for CAW is negative and that, as with ITC and CIT, including time lags of the tax competition variable and controlling for aggregate shocks are important elements in a properly specified econometric equation.

VI. Previous Empirical Studies

The empirical literature on fiscal competition has grown considerably in recent years, though the policy focus and methodologies used differ widely across studies. Among studies of "horizontal" (same level of government) competition, studies vary in whether they focus on expenditure policy or tax policy, and among tax policy studies, some focus on business taxes and some on consumer/personal taxes (see Brueckner (2003) and Zodrow (2010) for surveys). In terms of our policy focus on business taxes, the current paper is most closely related to Overesch and Rincke (2009), Devereux, Lockwood, and Redoano (2008) and, to a lesser extent, Altschuler and Goodspeed (2002) and Hayashi and Boadway (2001). All of these papers, except Overesch and Rincke, estimate a static model for some measure of corporate tax policy. All find that the

[25] In the United States, for the purposes of determining corporate income tax liability in a given state, corporations that do business in multiple states must apportion their national income to each state using formulary apportionment. The apportionment formula is always a weighted average of the company's sales, payroll, and property (with zero weights allowed). However, the weights in this formula vary by state, and there is no coordination among states. As shown in Figure 4, over the last forty years, states have increasingly moved toward increasing the weight on sales and decreasing the weights on payroll and property as a way to encourage job creation and investment in their state (and "export" the tax burden to foreign state business owners that sell goods and services in-state but employ workers and capital out-of-state). The capital (property) weight can be thought of as a capital tax instrument with similar effects as the corporate income tax, though it receives relatively much less attention by the public than the CIT.

slope of the reaction function is positive, as do we when we use the static model or omit controls for aggregate effects.[26]

Overesch and Rincke estimate a tax competition model using panel data on corporate income tax rates for EU countries. They control for time and country fixed effects, though they do not allow for common correlated effects. Similar to our results, they find that the estimated slope of the reaction function is positively biased if one omits time effects. However, while reduced, their estimated slope parameters remain positive after the addition of time fixed effects. A more significant difference in methodology between Overesch and Rincke and the current paper is the manner in which dynamics are modeled. Based on a partial adjustment model, Overesch and Rincke capture dynamics with a lagged dependent variable, which, as noted in Section V.B, restricts the sign of the long-run effect to be the same as the sign of the short-run effect. Our more general estimator allows for the possibility that the short-run and long-run effects have different signs. As shown in our above empirical results, such flexibility proves important for accurately estimating the reaction function slope.

An important contribution of our paper is to document the sensitivity of estimated reaction function slopes to the tax variable. Our preferred specification uses statutory tax variables because they are directly chosen by policymakers. Motivated by a tax competition model in which both capital and corporate income are mobile (the latter via transfer pricing), Devereux, Lockwood, and Redoano (2008) estimate a two-equation system with the statutory corporate income tax rate and the effective marginal tax rate (EMTR) on capital as dependent variables. For 21 OECD countries, they find a positive and significant slope for the statutory rate but a small and insignificant slope for the EMTR. These results are broadly consistent with our results for U.S. states when we estimate a similar static specification (cf. Table 3 (for ITC and CIT) and Panel A of Table 7 (for TWC)). Altschuler and Goodspeed (2002) and Hayashi and Boadway (2001) are somewhat less comparable to our study because they estimate reaction functions for the average effective corporate income tax rate – corporate income tax revenues divided by total corporate income (or GDP in Altschuler and Goodspeed) – rather than for statutory tax rates. Our results in Panel B of Table 7 suggest that there can be a great deal of difference in estimated reaction function slopes when tax policy is measured by marginal and

[26] Empirically estimated reaction functions with negative slopes are rarely found in the economics literature. The only exceptions about which we are aware are the papers of non-capital tax rates by Brueckner and Saavedra (2001), who consider property tax competition among municipalities in the Boston metropolitan area, and Parchet (2014), who studies personal income tax competition among Swiss municipalities.

average tax rates. The key distinction between these three papers and ours is that none of them allows for lagged responses to foreign state tax policies or for common aggregate time effects.

There are several papers that estimate models of other forms of fiscal competition as well. These also typically do not control for aggregate time effects or lagged responses. Egger, Pfaffermayr, and Winner (2005a, b), Besley and Case (1995), and Case, Rosen, and Hines (1993) use panel data to estimate static models, and all of these papers report a positively sloped reaction function. Among these papers, only Egger, Praffermayr, and Winner and Case, Rosen, and Hines include both jurisdictional and time fixed effects, but they do not allow for lagged responses. Revelli (2002), Brueckner and Savaadra (2001), and Heyndels and Vuchelen (1998) estimate cross-section models, and they too report reaction functions with positive slopes. The main methodological differences between our paper and the studies discussed in this paragraph are our inclusion of both time fixed effects and a distributed time lag of tax policy in foreign states. Though most of these studies look at measures of fiscal policy different from those in the current study, our empirical findings suggest that the positive reaction function slopes found in these studies may be upwardly biased due to the omission of time fixed effects or the restriction to only contemporaneous responses.[27]

VII. Summary and Conclusions

This paper estimates a capital tax reaction function motivated by strategic tax competition theory. We estimate this model using state panel data from 1965-2006 for several measures of capital tax policy. Our key empirical findings are that the slope of the reaction function for the investment tax credit (ITC) is negative and statistically different from zero and the slope of the reaction function for the corporate income tax (CIT) is negative but not statistically different from zero. These findings are consistent with the implications of our theoretical model that 1) the slope of the reaction function can be positive, negative, or zero depending on a key elasticity and

[27] All of the above papers are drawn from the economics literature. Tax competition and reaction functions have also been studied in the political science literature. Hanson (1993) concludes that "competition from neighboring states has little impact on development choices." Mooney (2001) argues that most prior empirical studies of the policy diffusion process among states are biased upward because they do not control for aggregate time effects. He then shows that the reaction function slope for states' decisions to adopt a personal income tax turns from positive and significant to either small and insignificant or negative, depending on the exact specification, when aggregate time effects enter the econometric equation.

2) tax policies targeting new, more mobile capital like the ITC should have a larger reaction function slope than policies targeting total (new and old) capital. We document that including time lags of foreign state tax policy and conditioning on aggregate shocks are vitally important in accurately estimating this slope. The results prove robust in several dimensions, including defining tax policy in terms of the capital apportionment weight (CAW) or the tax wedge on capital (TWC).

While these results are striking given prior findings in the literature and the casual observation that state capital tax rates, on the whole, have fallen over time, they are not surprising. The negative sign is fully consistent with the qualitative and quantitative implications of the theoretical model developed in this paper. The model illustrates how, if state residents respond to positive income shocks by disproportionate spending on private goods versus public goods, a state may react to a tax increase in a foreign state (or more precisely, to the income windfall resulting from the tax-induced capital inflow from the foreign state) by reducing its own tax rate. The model highlights the crucial role played by the income elasticity of private goods relative to public goods, an elasticity related to whether private goods as a whole are a luxury or necessary good or whether Wagner's Law is valid. Our empirical findings suggest that, while state capital taxation has eased dramatically in recent decades, the downward pressure is not coming from tax competition – i.e., how states respond to each other – but from aggregate shocks impacting all states in more or less the same way. Rather than states "racing to the bottom" which suggests a competition in which participants respond to each other's movements in the same direction, our findings indicate that tax competition is better characterized by states "riding on a seesaw."

An important implication of this result is that calls for legislative, judicial, or regulatory actions aimed at restricting tax competition as a means of stemming the fall in state capital tax revenue or the mobility of capital are likely misguided. In fact, similar calls in the European Union might also be inappropriate.[28] If aggregate shocks, not tax competition, are driving the secular trends in capital taxation, both in the U.S. and Europe, attenuating tax competition will do little to stop or reverse these trends.[29] This paper leaves open the question as to which

---

[28] Sutter (2007, p. 124) argues that the Code of Conduct for business taxation was adopted by the EC Commission in 1997 in light of an "intense discussion about unfair tax competition among OECD and EC Member States in the late 1990s showing that national tax individualism ultimately leads to a harsh fiscal race to the bottom in attracting 'mobile' foreign industries and businesses."

[29] Nonetheless, there may well be other arguments for restricting tax competition. In particular, the

aggregate shocks may be responsible for the decline in capital income tax rates documented in Figures 1 to 4. One possibility is shocks to the aggregate capital income share. Our theoretical model shows that the equilibrium tax rate is negatively related to the pre-tax capital income share (see Appendix D, equation (D-8)). The secular increase in this share is well documented for the United States (Elsby, Hobijn, and Şahin, 2013) and worldwide (Karabarbounis and Neiman, 2014; Piketty, 2014), and future work needs to examine the quantitative relations between these secular movements and state tax policy.

The finding of a negative-sloping capital tax reaction function has several implications for the strategic tax competition models. First, the non-zero slope provides support for the empirical importance of strategic tax competition relative to other factors in tax setting behavior. The finding is a rejection of both the hypothesis that capital is immobile and the hypothesis that the supply of capital to the nation is perfectly elastic; either hypothesis implies a zero slope to the reaction function. Second, multi-stage or Stackelberg models of tax competition rely on a positively sloped reaction function for several results (Konrad and Schjelderup, 1999). The negatively sloped reaction function documented in this paper raises concerns about the existence, stability, and uniqueness of equilibrium in these classes of models.

The negative slope also suggests that the theory of yardstick competition, a leading alternative theory of fiscal strategic interaction and one that predicts a positive-sloping reaction function, is either not an important force in the setting of capital tax policy or is dominated by the force of tax competition.[30] Future research in this field might well focus on whether similar methodological improvements as those employed in this paper could unearth evidence of negative sloping reaction functions in other areas of fiscal policy, such as personal taxation, in which yardstick competition is likely to be a stronger force.

---

canonical strategic tax competition models of Oates (1972), Zodrow and Mieszkowski (1986), and Wilson (1986) and others yield an equilibrium with sub-optimally low taxes and public services, irrespective of the slope of the reaction function.

[30] A negatively sloped reaction function allows us to avoid the observational equivalence problem between yardstick and tax competition noted by Revelli (2005).

References

Altshuler, Rosanne, and Timothy J. Goodspeed. 2002. "Follow the Leader? Evidence on European and U.S. Tax Competition." *CUNY Working Paper*.

Andrews, Donald W.K. 1999. "Consistent Moment Selection Procedures for Generalized Method of Moments Estimation." *Econometrica*, 67(3): 543–564.

Andrews, Donald W.K., and Biao Lu. 2001. "Consistent Model and Moment Selection Criteria for GMM Estimation with Applications to Dynamic Panel Models." *Journal of Econometrics*, 101(1): 123–164.

Besley, Timothy, and Anne C. Case. 1995. "Incumbent Behavior: Vote-Seeking, Tax-Setting, and Yardstick Competition." *American Economic Review*, 85(1): 25–45.

Besley, Timothy, and Anne C. Case. 2003. "Political Institutions and Policy Choices: Evidence from the United States." *Journal of Economic Literature*, 41: 7-73.

Brueckner, Jan K. 2003. "Strategic Interaction Among Governments: An Overview of Empirical Studies." *International Regional Science Review*, 26(2): 175–88.

Brueckner, Jan K., and Luz A. Saavedra. 2001. "Do Local Governments Engage In Strategic Property-Tax Competition?" *National Tax Journal*, 54(2): 203–29.

Case, Anne C., Harvey S. Rosen, and James R. Hines, Jr. 1993. "Budget Spillovers and Policy Interdependence: Evidence From the States." *Journal of Public Economics*, 52(3): 285–307.

Coate, Stephen, and Stephen Morris. 1999. "Policy Persistence" *American Economic Review*, 89(5): 1327-1336.

De Mooij, Ruud A. and Hendrik Vrijburg. 2012. "Tax Rates as Strategic Substitutes." Tinbergen Institute Discussion Paper 104/VI.

Devereux, Michael P., Ben Lockwood, and Michela Redoano. 2007. "Horizontal and Vertical Indirect Tax Competiton: Theory and Some Evidence from the USA." *Journal of Public Economics*, 91: 451-479.

Devereux, Michael P., Ben Lockwood, and Michela Redoano. 2008. "Do Countries Compete Over Corporate Tax Rates?" *Journal of Public Economics*, 92(5-6): 1210-1235.

Donald, Stephen G., and Whitney K. Newey. 2001. "Choosing the Number of Instruments." *Econometrica*, 69(5): 1161–1191.

Egger, Peter, Michael Pfaffermayr, and Hannes Winner. 2005a. "Commodity Taxation in a 'Linear' World: a Spatial Panel Data Approach." *Regional Science and Urban Economics*, 35(5): 527–41.

Egger, Peter, Michael Pfaffermayr, and Hannes Winner. 2005b. "An Unbalanced Spatial Panel Data Approach to US State Tax Competition." *Economics Letters*, 88(3): 329–35.

Elsby, Michael W.L., Hobijn, Bart, and Şahin, Ayşegül. 2013. "The Decline of the U.S. Labor Share." *Brookings Papers on Economic Activity* 2013:2 (forthcoming).

Enrich, Peter D. 2007. "A Defense of the Commerce Clause's Role in Constraining State Business Tax Incentives." *National Tax Association, Proceedings of 99th Annual Conference on Taxation*, 22-29.

Goolsbee, Austan. 2004. "The Impact of the Corporate Income Tax: Evidence from State Organizational Form Data." *Journal of Public Economics*, 88: 2283-2299.

Hansen, Christian, Jerry Hausman, and Whitney Newey. 2008. "Estimation with Many Instrumental Variables." *Journal of Business and Economic Statistics*, 26(4): 398–422.

Hanson, Russell L. 1993. "Bidding for Business: A Second War between the States?" *Economic Development Quarterly*, 7(2): 183-198.

Haufler, Andreas, and Ian Wooton. 1999**.** "Country Size and Tax Competition for Foreign Direct Investment." *Journal of Public Economics,* 71: 121-139.

Hayashi, Masayoshi, and Robin Boadway. 2001. "An Empirical Analysis of Intergovernmental Tax Interaction: The Case of Business Income Taxes in Canada ." *Canadian Journal of Economics*, 34(2): 481–503.

Heyndels, Bruno, and Jef Vuchelen. 1998. "Tax Mimicking Among Belgian Municipalities." *National Tax Journal*, 51(1): 89–101.

Houthakker, Hendrik S. 1960. "Additive Preferences." *Econometrica*, 28(2): 244-257.

Jacobs, Jan P.A.M., Jenny E. Ligthart, and Hendrik Vrijburg, 2010. "Consumption Tax Competition among Governments: Evidence from the United States." *International Tax and Public Finance*, 17: 271-294.

Kapoor, Mudit, Harry H. Kelejian, and Ingmar R. Prucha. 2007. "Panel Data Models With Spatially Correlated Error Components." *Journal of Econometrics*, 140(1): 97–130.

Karabarbounis, Loukas, and Brent Neiman. 2014. "The Global Decline of the Labor Share." *Quarterly Journal of Economics,* 129 (February): 61-103.

Keen, Michael, and Konrad Kai A. 2013. "The Theory of International Tax Competition and Coordination." In *Handbook of Public Economics, Volume 5, eds.* Alan J. Auerbach, Raj Chetty, Martin Feldstein, and Emmanuel Saez, 257-328. Amsterdam & Oxford, Elsevier.

Konrad, Kai A., and Guttorm Schjelderup. 1999. "Fortress Building in Global Tax Competition." *Journal of Urban Economics*, **46(1),** 156-167.

Kreps, David M. 1990. *A Course in Microeconomic Theory*. Princeton: Princeton University Press.

Lucas, Robert E., Jr. 1990. "Why Doesn't Capital Flow from Rich to Poor Countries?" *The American Economic Review* 80 (2), 92-96.

Mackie-Mason, Jeffrey K., and Roger H. Gordon, 1997. "How Much Do Taxes Discourage Incorporation?" *Journal of Finance*, 52(2): 477-505.

McLure, Charles E., Jr. 2008. "Harmonizing Corporate Income Taxes in the European Community: Rationale and Implications." In *Tax Policy and the Economy, Volume 22*, ed. James Poterba, 151-195. Chicago: University of Chicago Press (for the NBER).

Mendoza, Enrique G., and Linda L. Tesar, 2005. "Why Hasn't Tax Competition Triggered a Race to the Bottom? Some Quantitative Lessons from the EU." *Journal of Monetary Economics*, 52: 163-204.

Mintz, Jack, and Henry Tulkens. 1986. "Commodity Tax Competition between Member States of a Federation: Equilibrium and Efficiency." *Journal of Public Economics*, 29(2): 133–172.

Mooij, Ruud A., and Nicodème, Gaëtan. 2008. "Corporate Tax Policy and Incorporation in the EU." *International Tax and Public Finance*, 15(4): 478-498.

Mooney, Christopher Z. 2001. "Modeling Regional Effects on State Policy Diffusion." *Political Research Quarterly*, 54(1): 103-124.

Murphy, Kevin M., and Robert Topel. 1985. "Estimation and Inference in Two-Step Econometric Models." *Journal of Business and Economic Statistics,* 3(4): 370-380.

Nickell, Stephen. 1981. "Biases in Dynamic Models with Fixed Effects." *Econometrica*, 49(6): 417–26.

Oates, Wallace E. 1972. *Fiscal Federalism*. New York: Harcourt Brace.

Overesch, Michael, and Johannes Rincke. 2009. "What Drives Corporate Tax Rates Down? A Reassessment of Globalization, Tax Competition, and Dynamic Adjustment to Shocks." CESifo Working Paper 2535.

Piketty, Thomas. 2014. *Capital in the Twenty-First Century*. Cambridge: Harvard University.

Parchet, Raphaël. 2014. "Are Local Tax Rates Strategic Complements of Strategic Substitues?" IdEP Economic Papers 2014/07, University of Lausanne.

Pagan, Adrian. 1984. "Econometric Issues in the Analysis of Regressions with Generated Regressors." *International Economic Review*, 25(1): 221-247.

Pesaran, M. Hashem. 2006. "Estimation and Inference in Large Heterogeneous Panels with a Multifactor Error Structure." *Econometrica*, 74(4): 967–1012.

Plesko, George A. 2003. "An Evaluation of Alternative Measures of Corporate Tax Rates." *Journal of Accounting and Economics*, 35: 201-226.

Ram, Rati. 1987. "Wagner's Hypothesis in Time-Series and Cross-Section Perspectives: Evidence from 'Real' Data for 115 Countries." *Review of Economics and Statistics*, 69: 194–204.

Razin, Assaf, and Efraim Sadka, 2011. "Tax Competition and Migration: The Race-to-the-Bottom Hypothesis Revisited." *Migration and the Welfare State: Political Economy and Policy Formation*. Cambridge: MIT Press.

Reed, W. Robert. 2006. "Democrats, Republicans, and Taxes: Evidence that Political Parties Matter." *Journal of Public Economics* 90: 725-750.

Revelli, Federico. 2002. "Testing the Tax Mimicking Versus Expenditure Spill-Over Hypotheses Using English Data." *Applied Economics*, 34(14): 1723–31.

Revelli, Federico. 2005. "On Spatial Public Finance Empirics," *International Tax and Public Finance*, 12: 475-492.

Rose, Andrew K., and Mark M. Speigel, 2007. "Offshore Financial Centres: Parasites or Symbionts." *Economic Journal*, 117, 1310-1335.

Snyder, James, and Timothy Groseclose, 2000. "Estimating Party Influence in Congressional Roll-Call Voting." *American Journal of Political Science*, 44: 187-205.

Stark, Kirk J., and Daniel J. Wilson, 2006. "What Do We Know about the Interstate Effects of State Tax Incentives?" *The Georgetown Journal of Law & Public Policy* 4 (Winter 2006): 133-164.

Stock, James H., and Motohiro Yogo. 2005. "Testing for Weak Instruments in Linear IV Regression." In *Identification and Inference for Econometric Models: Essays in Honor of Thomas Rothenberg,* eds. Donald W.K. Andrews and James H. Stock, 80–108. Cambridge: Cambridge University Press.

Story, Louise. 2012. "The United States of Subsidies." *New York Times*. http://www.nytimes.com/2012/12/02/us/how-local-taxpayers-bankroll-corporations.html

Sutter, Franz Philipp. 2007. "The Influence of the European State Aid Rules on National Tax Policy." In *National Tax Policy in Europe: To Be or Not to Be,* eds. Krister Andersson, Eva Eberhartinger, and Lars Oxelheim, 121-164. Berlin: Springer.

U.S. Department of the Treasury. 2007. "Treasury Conference on Business Taxation and Global Competitiveness: Background Paper." Washington, DC: U.S. Department of the Treasury.

Walker, Scott. 2011. "Governor Walker Statement on Illinois Tax Increase: 'Wisconsin Is Open for Business.'" Madison, Wisconsin: State of Wisconsin.

Wildasin, David E. 2007. "Comments: 'A Defense of the Commerce Clause's Role in Constraining State Business Tax Incentives' by Peter D. Enrich, 'A Market for Jobs Approach for Analyzing the Competition for Capital' by Ann Markusen, and 'State Investment Tax Incentives: What Are the Facts?' by Robert S. Chirinko and Daniel J. Wilson." *National Tax Association, Proceedings of 99th Annual Conference on Taxation* (CD-ROM): 45-49.

Wilson, John Douglas. 1986. "A Theory of Interregional Tax Competition." *Journal of Urban Economics*, 19(3): 296-315.

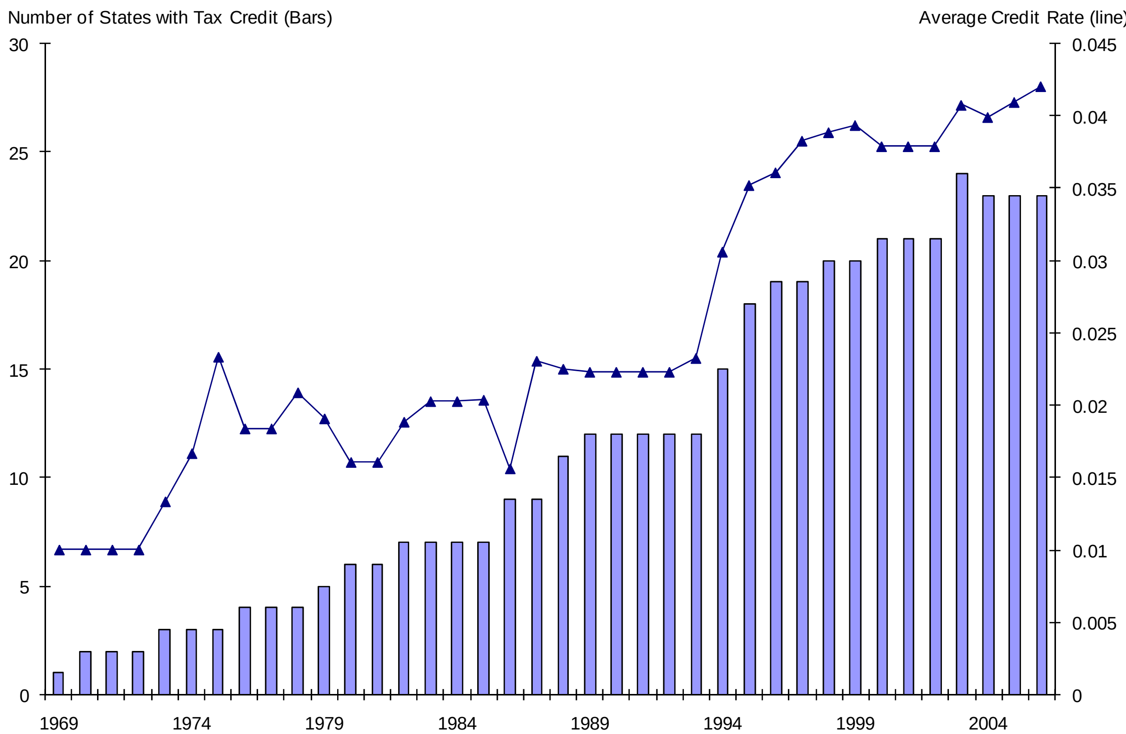
Wilson, John Douglas, and Eckhard Janeba. 2005. "Decentralization and International Tax Competition." *Journal of Public Economics*, 89(7): 1211–1229.

Zodrow, George R. 2010. "Capital Mobility and Capital Tax Competition." *National Tax Journal*, 63(4, Part 2): 865-902.

Zodrow, George R., and Peter Mieszkowski. 1986. "Pigou, Tiebout, Property Taxation, and the Underprovision of Local Public Goods." *Journal of Urban Economics,* 19(3): 356–370.

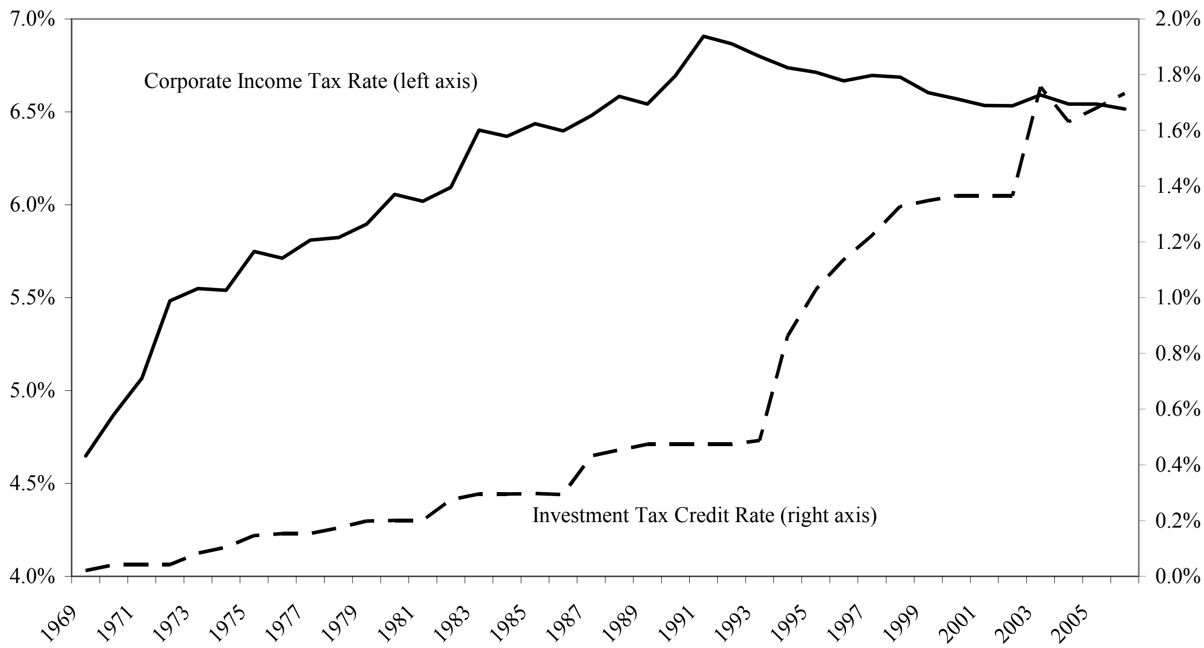
Figure 1. State Investment Tax Credit Rates

1969 To 2006



Notes to Figure 1: The number of states with an investment tax credit is indicated on the left vertical axis; the average credit rate (an unweighted average across only those states with a credit) is indicated on the right vertical axis. See Appendix A for details concerning the construction of the variables.

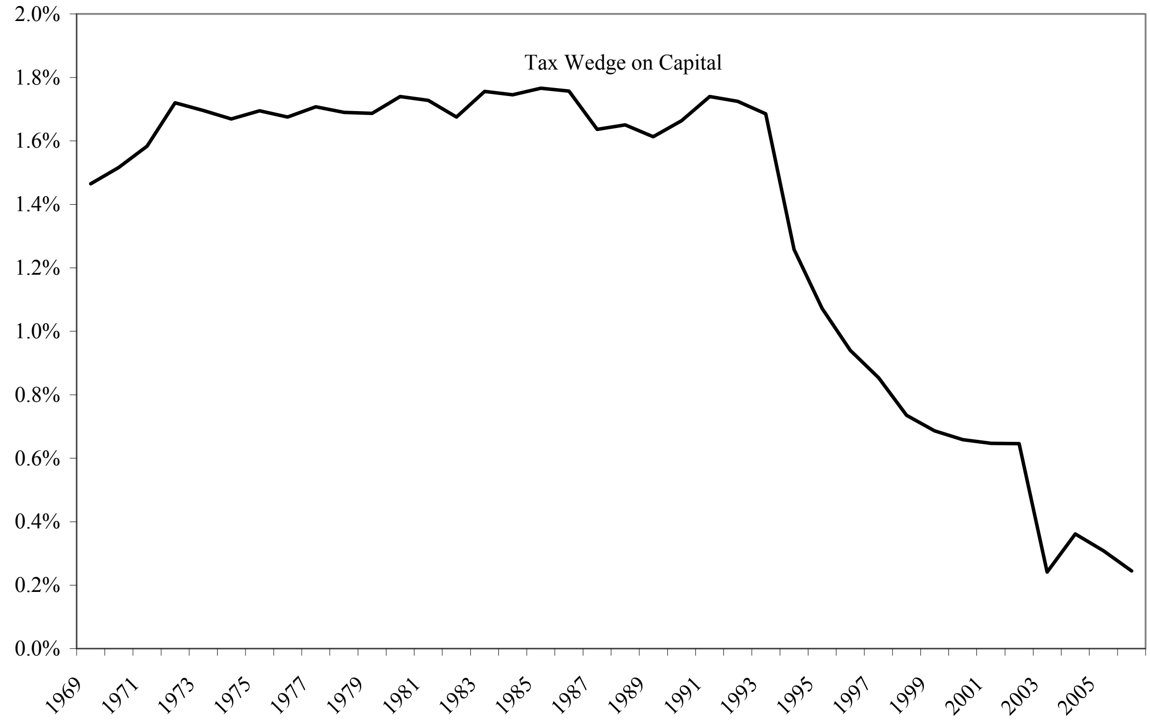
Figure 2. National Averages Of State Investment Tax Credit And Corporate Income Tax Rates 1969 To 2006



Notes to Figure 2: Averages are calculated over all 50 states (unweighted) and exclude the District of Columbia. Both rates are measured by the top marginal rate. See Appendix A for details concerning the construction of the variables.

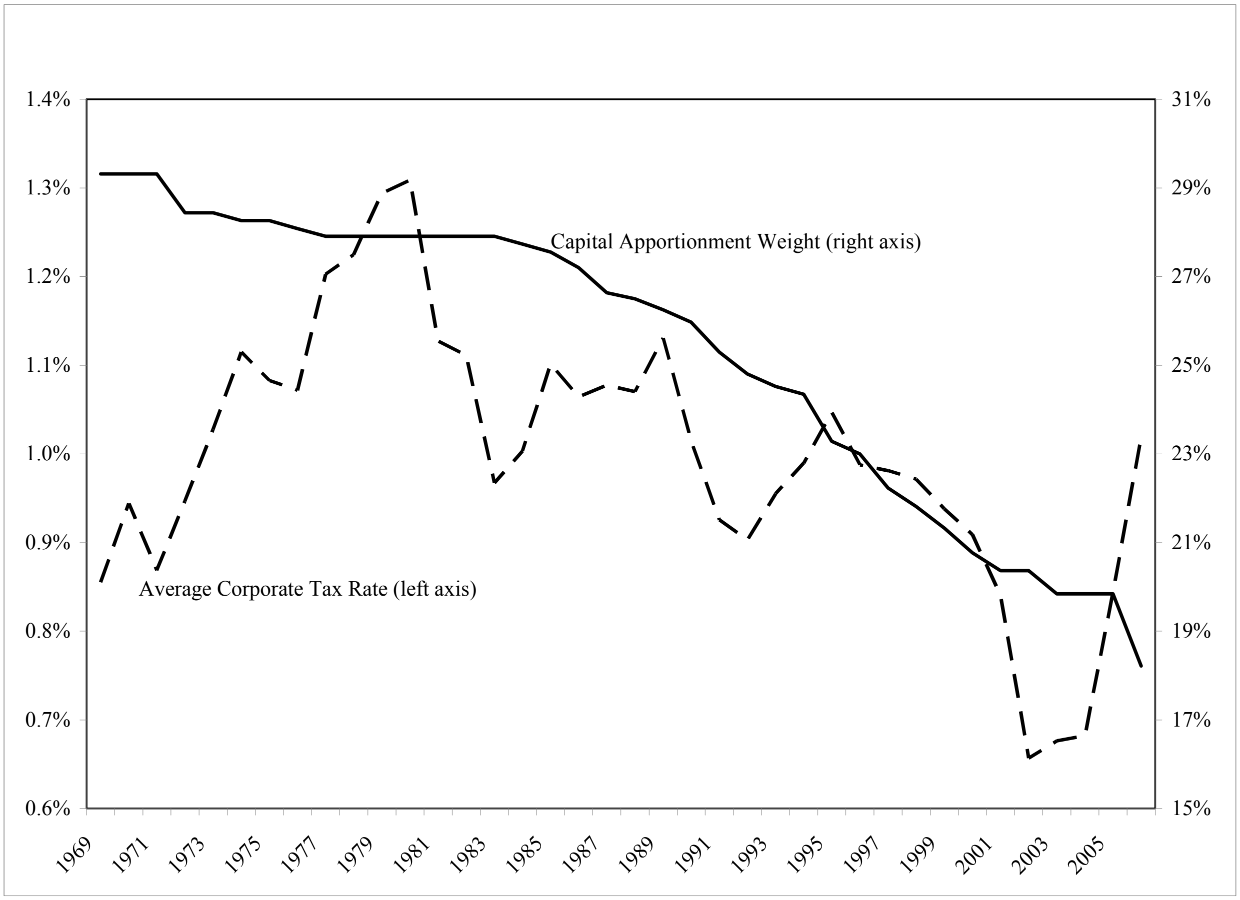
Figure 3. National Average Of State Tax Wedge On Capital

1969 To 2006



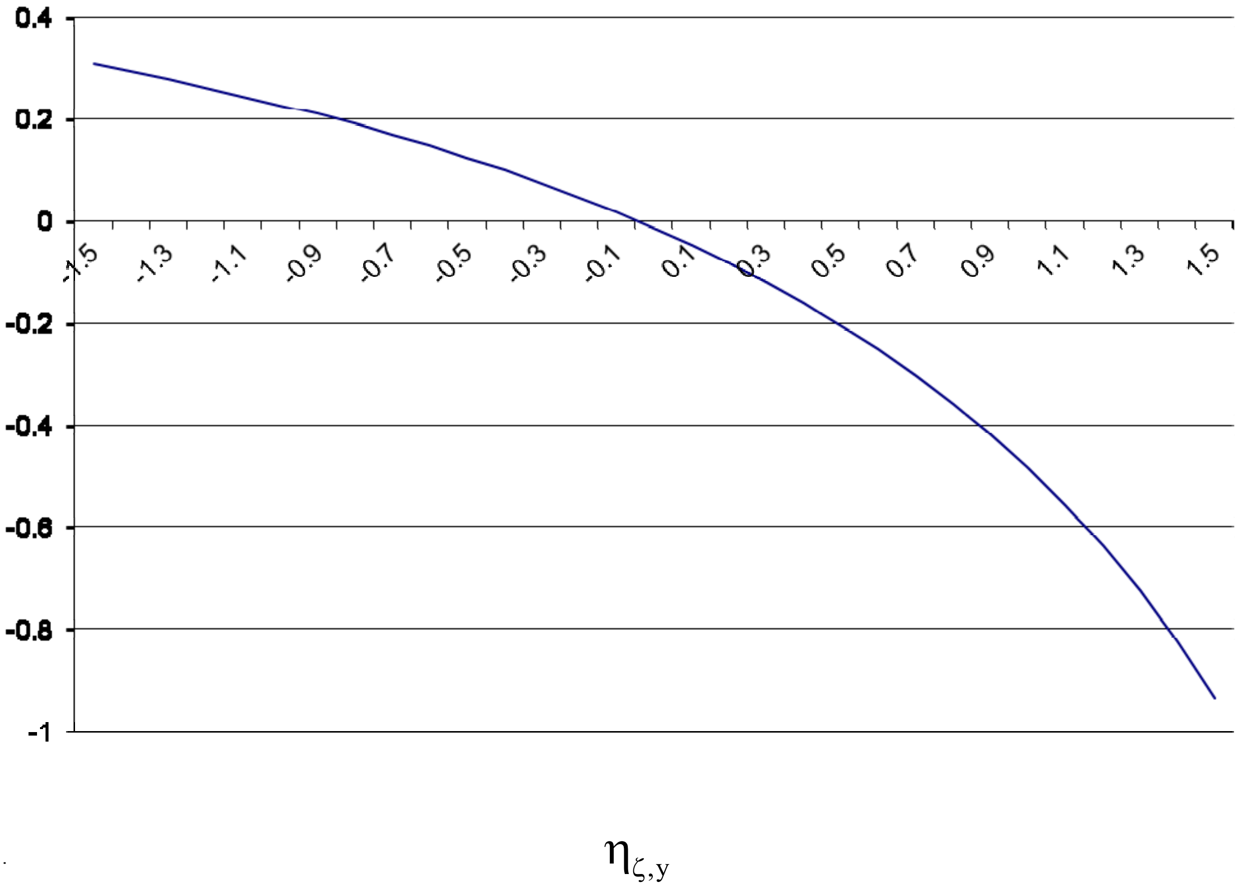
Notes to Figure 3: Averages are calculated over all 50 states (unweighted) and exclude the District of Columbia. See footnote 1 and Appendix A for details concerning the construction of the variable.

Figure 4. National Averages Of Capital Apportionment Weight
And Average Corporate Tax Rate
1969 To 2006



Notes to Figure 4: Averages are calculated over all 50 states (unweighted) and exclude the District of Columbia. See Appendix A for details concerning the construction of the capital apportionment weight variable. The average corporate tax rate variable is the ratio of state tax revenues from corporate taxes, severance taxes, and license fees to total state business income, the latter measured by gross operating surplus.

Figure 5: Slope Of The Reaction Function



Notes to Figure 5: This figure plots the theoretical slope of the reaction function (equation (11)) on the vertical axis against values of $\eta_{\zeta,y}$ ranging from -1.50 to +1.50 in increments of 0.10 on the horizontal axis. These computations are based on the following assumptions: $\eta_{y,K} = 0.33$, $-\eta_{K,\tau} = 1.00$, $\zeta = 3.701$, $\tau\pi = 0.003$, and $s = 0.025$. The latter three parameters are estimated from NIPA data as averages for the period 2000-2009: ζ is computed as the ratio of consumption (NIPA Table 1.1.5) to total government spending (federal, state, and local, (NIPA Table 1.1.5); $\tau\pi$ and s are computed as tax receipts (NIPA Table 3.20) relative to GDP (NIPA Table 1.1.5)).

Table 1
Tax Policy (τ): Investment Tax Credit Rate ("New Capital")
Common Correlated Effects Pooled (CCE) IV Estimator and
Various Time Lags of Tax Competition Variable

	(A)	(B)	(C)	(D)	(E)
	Number of Time Lags of $\tau^f_{i,t}$:				
	0	1	2	3	4
A. Competitive States Tax Variable					
$\tau^f_{i,t}$	1.301 (0.059)	-1.309 (0.497)	-1.572 (0.502)	-1.473 (0.462)	-1.499 (0.469)
$\tau^f_{i,t-1}$	------	0.732 (0.474)	0.578 (0.551)	0.527 (0.507)	0.548 (0.515)
$\tau^f_{i,t-2}$	------	------	0.309 (0.189)	0.047 (0.266)	0.047 (0.269)
$\tau^f_{i,t-3}$	------	------	------	0.310 (0.261)	0.335 (0.376)
$\tau^f_{i,t-4}$	------	------	------	------	-0.028 (0.270)
α = Sum of Coefficients on the $\tau^f_{i,t}$'s	1.301 (0.059) [0.000]	-0.577 (0.146) [0.000]	-0.686 (0.159) [0.000]	-0.588 (0.170) [0.001]	-0.596 (0.175) [0.001]
B. Control Variables					
$\text{PREFERENCES}_{i,t-1}$	0.001 (0.001)	-0.002 (0.001)	-0.002 (0.001)	-0.002 (0.001)	-0.002 (0.001)
$\text{IK}_{i,t-1}$	0.005 (0.004)	-0.003 (0.004)	-0.003 (0.004)	-0.003 (0.004)	-0.003 (0.004)
$\text{POPULATION}_{i,t}$	-0.014 (0.002)	-0.014 (0.001)	-0.014 (0.001)	-0.014 (0.002)	-0.013 (0.002)
$\text{IK}^f_{i,t-1}$	0.006 (0.005)	-0.030 (0.011)	-0.038 (0.011)	-0.036 (0.011)	-0.037 (0.012)
$\text{POPULATION}^f_{i,t}$	0.019 (0.004)	-0.007 (0.007)	-0.012 (0.007)	-0.012 (0.007)	-0.014 (0.007)
Cross-Section Dependence	Yes	Yes	Yes	Yes	Yes
State Fixed Effects	Yes	Yes	Yes	Yes	Yes
C. Instrument Assessment					
p-value for test of overidentifying restrictions	0.644	0.820	0.872	0.855	0.801
Minimum eigenvalue statistic	18.902	15.008	16.884	17.491	16.393

Table Notes After Table 6

Table 2
Tax Policy (τ): Corporate Income Tax Rate ("Old and New Capital")
Common Correlated Effects Pooled (CCE) IV Estimator and
Various Time Lags of Tax Competition Variable

	(A)	(B)	(C)	(D)	(E)
	Number of Time Lags of $\tau^f_{i,t}$:				
	0	1	2	3	4
A. Competitive States Tax Variable					
$\tau^f_{i,t}$	0.512 (0.206)	0.378 (0.430)	0.569 (0.470)	0.575 (0.375)	0.693 (0.366)
$\tau^f_{i,t-1}$	------	-0.382 (0.431)	-0.836 (0.418)	-0.752 (0.389)	-0.843 (0.385)
$\tau^f_{i,t-2}$	------	------	0.130 (0.326)	0.392 (0.500)	0.415 (0.509)
$\tau^f_{i,t-3}$	------	------	------	-0.292 (0.293)	-0.022 (0.396)
$\tau^f_{i,t-4}$	------	------	------	------	-0.291 (0.192)
α = Sum of Coefficients on the $\tau^f_{i,t}$'s	0.512 (0.206) [0.013]	-0.004 (0.182) [0.981]	-0.138 (0.210) [0.513]	-0.077 (0.192) [0.690]	-0.048 (0.202) [0.813]
B. Control Variables					
$PREFERENCES_{i,t-1}$	-0.005 (0.001)	-0.002 (0.001)	-0.002 (0.001)	-0.002 (0.001)	-0.002 (0.001)
$IK_{i,t-1}$	-0.009 (0.009)	-0.001 (0.005)	-0.001 (0.005)	-0.001 (0.005)	-0.001 (0.005)
$POPULATION_{i,t}$	-0.007 (0.003)	-0.020 (0.003)	-0.018 (0.003)	-0.018 (0.003)	-0.018 (0.003)
$IK^f_{i,t-1}$	-0.135 (0.023)	0.014 (0.012)	0.011 (0.014)	0.011 (0.012)	0.015 (0.013)
$POPULATION^f_{i,t}$	-0.055 (0.007)	-0.031 (0.009)	-0.040 (0.010)	-0.033 (0.009)	-0.035 (0.009)
Cross-Section Dependence	Yes	Yes	Yes	Yes	Yes
State Fixed Effects	Yes	Yes	Yes	Yes	Yes
C. Instrument Assessment					
p-value for test of overidentifying restrictions	0.292	0.325	0.288	0.304	0.206
Minimum eigenvalue statistic	117.913	39.974	37.007	39.647	34.999

Table Notes After Table 6

Table 3
Estimated Slope of Reaction Function For Each Tax Policy
(α = Sum of Coefficients on the $\tau^{f}_{i,t}$'s)
Various IV Estimators and Time Lags of Tax Competition Variable

	(A)	(B)	(C)	(D)	(E)
	Number of Time Lags of $\tau^{f}_{i,t}$:				
	0	1	2	3	4
A. Investment Tax Credit Rate					
"New Capital"					
Common Correlated Effects Pooled (CCE)	1.301	-0.577	-0.686	-0.588	-0.596
	(0.059)	(0.146)	(0.159)	(0.170)	(0.175)
	[0.000]	[0.000]	[0.000]	[0.001]	[0.001]
Two-way Fixed Effects (TFE)	7.534	-1.425	-1.512	-1.584	-1.749
	(2.770)	(0.312)	(0.370)	(0.375)	(0.436)
	[0.007]	[0.000]	[0.000]	[0.000]	[0.000]
One-way (state) fixed effects (NTFE)	1.670	0.308	0.297	0.285	0.272
	(0.180)	(0.115)	(0.120)	(0.128)	(0.139)
	[0.000]	[0.007]	[0.013]	[0.026]	[0.050]
B. Corporate Income Tax Rate					
"Old and New Capital"					
Common Correlated Effects Pooled (CCE)	0.512	-0.004	-0.138	-0.077	-0.048
	(0.206)	(0.182)	(0.210)	(0.192)	(0.202)
	[0.013]	[0.981]	[0.513]	[0.690]	[0.813]
Two-way Fixed Effects (TFE)	1.418	0.760	0.778	0.781	0.817
	(0.173)	(0.809)	(0.832)	(0.817)	(0.818)
	[0.000]	[0.347]	[0.350]	[0.339]	[0.318]
One-way (state) fixed effects (NTFE)	1.030	0.767	0.689	0.646	0.566
	(0.133)	(0.163)	(0.165)	(0.170)	(0.177)
	[0.000]	[0.000]	[0.000]	[0.000]	[0.001]

Table Notes After Table 6

Table 4
Estimated Slope of Reaction Function For Each Tax Policy
(α = Sum of Coefficients on the $\tau^{f}_{i,t}$'s)
Two CCE IV Estimators and Various Time Lags of Tax Competition Variable

	(A)	(B)	(C)	(D)	(E)
	Number of Time Lags of $\tau^{f}_{i,t}$:				
	0	1	2	3	4
A. Investment Tax Credit Rate "New Capital"					
CCE-Unrestricted/Inefficient	0.493	-0.916	-0.834	-0.614	-0.428
	(0.812)	(0.320)	(0.361)	(0.353)	(0.397)
	[0.543]	[0.004]	[0.021]	[0.082]	[0.281]
CCE-Restricted/Efficient	1.301	-0.577	-0.686	-0.588	-0.596
	(0.059)	(0.146)	(0.159)	(0.170)	(0.175)
	[0.000]	[0.000]	[0.000]	[0.001]	[0.001]
B. Corporate Income Tax Rate "Old and New Capital"					
CCE-Unrestricted/Inefficient	0.951	-0.202	-0.142	-0.007	-0.090
	(0.338)	(0.324)	(0.387)	(0.404)	(0.410)
	[0.005]	[0.533]	[0.714]	[0.987]	[0.827]
CCE-Restricted/Efficient	0.512	-0.004	-0.138	-0.077	-0.048
	(0.206)	(0.182)	(0.210)	(0.192)	(0.202)
	[0.013]	[0.981]	[0.513]	[0.690]	[0.813]

Table Notes After Table 6

Table 5:
Estimated Slope of Reaction Function For Each Tax Policy
(α = Sum of Coefficients on the $\tau^{f}_{i,t}$'s)

Various IV Estimators and Time Lags of All Regressors

	(A)	(B)	(C)	(D)	(E)
	Number of Time Lags for all regressors:				
	0	1	2	3	4
A. Investment Tax Credit Rate					
"New Capital"					
Common Correlated Effects Pooled (CCE)	1.301	-1.271	-2.774	-1.779	-3.255
	(0.059)	(0.144)	(0.326)	(0.157)	(0.457)
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Two-way Fixed Effects (TFE)	7.534	-1.173	-1.280	-1.282	-0.651
	(2.770)	(0.452)	(0.585)	(0.588)	(2.392)
	[0.007]	[0.009]	[0.029]	[0.029]	[0.786]
One-way (state) fixed effects	1.670	0.527	0.513	0.591	0.400
	(0.180)	(0.394)	(0.378)	(3.082)	(0.429)
	[0.000]	[0.181]	[0.175]	[0.848]	[0.351]
B. Corporate Income Tax Rate					
"Old and New Capital"					
Common Correlated Effects Pooled (CCE)	0.512	-0.118	-0.308	-0.134	-2.195
	(0.206)	(0.274)	(0.317)	(0.290)	(0.349)
	[0.013]	[0.668]	[0.331]	[0.644]	[0.000]
Two-way Fixed Effects (TFE)	1.418	1.207	0.749	0.384	0.275
	(0.172)	(0.988)	(0.879)	(0.830)	(0.457)
	[0.000]	[0.222]	[0.395]	[0.643]	[0.000]
One-way (state) fixed effects	1.030	0.686	0.489	0.484	0.322
	(0.133)	(0.200)	(0.192)	(0.301)	(0.419)
	[0.000]	[0.001]	[0.011]	[0.107]	[0.443]

Table Notes After Table 6

Table 6
Estimated Slope of Reaction Function For Alternative Tax Policy Measures
(α = Sum of Coefficients on the $\tau^{f}_{i,t}$'s)
Various IV Estimators and Time Lags of Tax Competition Variable

	Number of Time Lags of $\tau^{f}_{i,t}$:				
	0	1	2	3	4
A. Tax Wedge On Capital					
Common Correlated Effects Pooled (CCE)	1.062	-1.356	-1.352	-1.371	-1.430
	(0.064)	(0.156)	(0.160)	(0.164)	(0.161)
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Two-way Fixed Effects (TFE)	1.288	-1.274	-1.326	-1.448	-1.551
	(4.644)	(0.429)	(0.461)	(0.464)	(0.503)
	[0.782]	[0.003]	[0.004]	[0.002]	[0.002]
One-way (state) fixed effects	1.321	1.021	1.131	1.125	1.124
	(0.158)	(0.787)	(0.811)	(0.740)	(0.751)
	[0.000]	[0.195]	[0.163]	[0.129]	[0.135]
B. Average Corporate Tax Rate					
Common Correlated Effects Pooled (CCE)	1.103	-0.569	-0.440	2.267	2.287
	(0.039)	(0.196)	(0.243)	(0.144)	(0.122)
	[0.000]	[0.004]	[0.070]	[0.000]	[0.000]
Two-way Fixed Effects (TFE)	2.484	0.801	0.939	0.942	0.945
	(0.128)	(0.509)	(0.357)	(0.404)	(0.403)
	[0.000]	[0.116]	[0.009]	[0.020]	[0.019]
One-way (state) fixed effects	0.919	1.049	1.089	1.108	1.116
	(0.107)	(0.052)	(0.072)	(0.082)	(0.084)
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
C. Capital Apportionment Weight					
Common Correlated Effects Pooled (CCE)	1.904	-2.045	-2.126	-2.209	-2.333
	(0.075)	(0.064)	(0.067)	(0.064)	(0.063)
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Two-way Fixed Effects (TFE)	2.089	-3.718	-3.825	-3.955	-4.131
	(1.239)	(0.250)	(0.263)	(0.294)	(0.282)
	[0.092]	[0.000]	[0.000]	[0.000]	[0.000]
One-way (state) fixed effects	0.942	0.297	0.317	0.337	0.359
	(0.209)	(0.077)	(0.077)	(0.074)	(0.071)
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]

Notes To The Tables:

Instrumental variable (IV) estimates are based on equation (21) (except for the unrestricted/inefficient estimates in Table 4) and panel data for 48 states for the period 1965 to 2006. Given the maximum of four time lags, the effective sample is for the period 1969 to 2006. To enhance comparability across models, the 1969 to 2006 sample is used for all estimates. Some of the tables differ with respect to the tax variables appearing as dependent and independent variables. The foreign states tax variable ($\tau^{f}_{i,t-n}$, $n = 0,...,4$) is defined in equation (15) as the spatial lag of the home state tax variable, $\tau_{i,t}$. The competitive set of states is defined by all states other than state *i*, and the spatial lag weights are the inverse of the distance between the population centroids for state *i* and that of a foreign state, normalized to sum to unity. There are three control variables: $\text{PREFERENCES}_{i,t-1}$ captures the political preferences of the state. This variable is the average of three indicator variables, is lagged one period to avoid endogeneity issues, and ranges from 0.0 to 1.0. The three indicator variables are (a) the political party of the governor (1 if Republican; 0 otherwise), (b) the political party controlling both houses of the legislature (1 if Republican; 0 otherwise), and (c) an interaction between the indicator variables defined in (a) and (b). $\text{IK}_{i,t-1}$ is the investment to capital ratio, lagged one period to avoid endogeneity issues. $\text{POPULATION}_{i,t}$ is the state population as measured by the U.S. Census Bureau. The CCE estimator requires cross-section averages (CSA) of the dependent and independent variables as additional regressors; see Section III for details. To account for the endogeneity of $\tau^{f}_{i,t}$, we project this variable against a set of instruments whose selection is discussed in Section III.C. See Section IV and Appendix A for further details about definitions and data sources for the model variables and instruments. Instrument validity is assessed in terms of the Hansen J statistic based on the overidentifying restrictions. The null hypothesis of instrument validity is assessed in terms of the p-values presented in the table. A p-value greater than an arbitrary critical value (e.g., 0.10)xx implies that the null hypothesis is sustained and that the instruments are not invalid. Instrument relevance is assessed in terms of the minimum eigenvalue statistic assessing the joint significance of the excluded instruments from the projection of $\tau^{f}_{i,t}$ on the included (i.e., control variables) and excluded instruments. The α parameter measures the slope of the reaction function ($\tau_{i,t}$ vs. $\tau^{f}_{i,t-n}$, $n = 0,...,4$) and is the sum of the coefficients on the included $\tau^{f}_{i,t-n}$ variable(s). Standard errors for the CCE estimates are robust to heteroskedasticity and clustering by year.

***** THE APPENDICES ARE NOT FOR PUBLICATION *****

Appendix A: Variable Definitions and Data Sources[31]

This appendix describes the construction of and data sources for the variables used in this study:

1. ACT: Average Corporate Tax Rate.
2. CAW: Capital Apportionment Weight.
3. CIT: Corporate Income Tax Rate.
4. I/K: Investment/Capital Ratio.
5. ITC: Investment Tax Credit Rate.
6. PERS: Personal Income Tax Rate
7. PREFERENCES: Voter Preferences.
8. POPULATION: Population.
9. TD: Tax Depreciation.
10. TWC: Tax wedge on capital.
11. $\omega_{i,j}$: Spatial Lag Weights.

The series are for the 48 contiguous states (indexed by subscript s) for the period 1963 to 2006 (indexed by subscript *t*), unless otherwise noted.[32] Each of the above series is described in a separate section. The general organizing principle for each section is to first define each of the series mentioned above and then discuss its components. For each component, general issues concerning the construction of the series (if pertinent) and then data sources are discussed. Section 11 contains a Legend with abbreviations and sources.

[31] In describing the raw data, we have taken some of the text in this data appendix directly from government publications.

[32] The most notable exception is that the Annual Survey of Manufacturers was not conducted from 1979 to 1981.

1. ACT: Average Corporate Tax Rate

The average corporate tax rate is measured as follows,

$$ACT_{i,t} = REV_{i,t}^{CIT} \Big/ GOS_{i,t} \text{ ,}$$

where $GOS_{i,t}$ is state private gross operating surplus and $REV_{i,t}^{CIT}$ is state government revenues from the corporate income tax.

Gross operating surplus data come from REA, and state tax revenues data comes from STC.

2. CAW: Capital Apportionment Weight

The capital apportionment weight (CAW) is the weight that the state assigns to capital (property) in its formula apportioning income among the multiple states in which firms generate taxable income. The apportionment formula is always a weighted average of the company's sales, payroll, and property (with zero weights allowed). However, the weights vary by state. In practice, the payroll and property weights are always equal, at least for the states and years in our sample, so that knowing one of the three weights for a state reveals the other two.

We construct data from 1963 – 2006 on the factor apportionment weights for each of the 48 contiguous states. We use a number of different sources. OMER provides information on the year in which each state first deviated from the traditional three-factor, equal weighting formula. Kelly Edmiston kindly provided data on apportionment weights for years 1997 and 2001 used in CESW. John Deskins kindly provided data panel data for 1985-2003 used in BDF. Lastly, we were able to obtain weights for various years from STH.

3. CIT: Corporate Income Tax Rate

The effective corporate income tax rate at the state level ($\tau_{i,t}^{E,S}$) is lower than the legislated (or statutory) corporate income tax rate ($\tau_{t}^{L,S}$) due to the deductibility (in some states) against state taxable income of taxes paid to the federal government.[33] Some states allow full deductibility of federal corporate income taxes from state taxable income; Iowa and Missouri allow only 50% deductibility; and some states allow no deductibility at all. The deductibility provision in state tax codes is represented by $\upsilon_{i,t} = \{1.0, 0.5, 0.0\}$, and the provisional effective corporate income tax rate at the state level ($\tau_{i,t}^{\#,E,S}$) is as follows,

$$\tau_{i,t}^{\#,E,S} = \tau_{t}^{L,S}\left(1 - \upsilon_{i,t}\tau_{i,t}^{\#,E,F}\right).$$

The effect of federal income tax deductibility is represented by the provisional *effective* corporate income tax rate at the federal level ($\tau_{i,t}^{\#,E,F}$, defined below).

The $\tau_{i,t}^{L,S}$ and $\upsilon_{i,t}$ series are obtained from several sources. For recent years, data are obtained primarily from various issues of BOTS and STH, as well as actual state tax forms. Data for earlier years are obtained from various issues of BOTS and SFFF. Additional information has been provided by TAXFDN. Many states have multiple legislated tax rates that increase stepwise with taxable income; we measure $\tau_{i,t}^{L,S}$ with the marginal legislated tax rate for the highest income bracket.

The effective corporate income tax rate at the federal level is lower than the legislated corporate income tax rate ($\tau_{t}^{L,F}$) due to the deductibility against federal taxable income of taxes paid to the state. The provisional effective corporate income tax rate at the federal level is as follows,

$$\tau_{i,t}^{\#,E,F} = \tau_{t}^{L,F}\left(1 - \tau_{i,t}^{\#,E,S}\right)$$

[33] In "corporate income" taxes we also include Texas' "franchise" tax, which has a very similar tax base as the traditional corporate income tax base.

The effect of state income tax deductibility is represented by the *effective* corporate income tax rate at the state level. The $\tau_t^{L,F}$ series is obtained from GRAVELLE, Table 2.1. Our database presents $\tau_t^{L,F}$ in percentage points.

It has not generally been recognized that, owing to deductibility of taxes paid to another level of government, the effective corporate income tax rates at the state and federal levels are functionally related to each other. As shown in the above equations, these interrelationships yield two equations in two unknowns, and thus can be solved for the effective corporate income tax rates at the state and federal levels, respectively, as follows,

$$\tau_{i,t}^{E,S} = \tau_{i,t}^{L,S}\left[1-\upsilon_{i,t}\tau_t^{L,F}\right] \Big/ \left[1-\upsilon_{i,t}\tau_{i,t}^{L,S}\tau_t^{L,F}\right],$$

$$\tau_{i,t}^{E,F} = \tau_t^{L,F}\left[1-\tau_{i,t}^{L,S}\right] \Big/ \left[1-\upsilon_{i,t}\tau_{i,t}^{L,S}\tau_t^{L,F}\right].$$

The overall corporate income tax rate is the sum of $\tau_{i,t}^{E,S}$ and $\tau_{i,t}^{E,F}$. In the limiting case where federal corporate income taxes are not deductible against state taxable income ($\upsilon_{i,t} = 0$), this sum reduces to the more frequently used formula, $\tau_{i,t}^{L,S} + \left(1-\tau_{i,t}^{L,S}\right)\tau_t^{L,F}$.

4. I/K: Investment/Capital Ratio

As a measure of investment demand, as well as overall economic activity in a state, we use the state’s investment-capital ratio. We extend data on this ratio used in Chirinko and Wilson (2008), which cover 1963 – 2004, through 2006. The primary raw source data is the Annual Survey of Manufacturers (ASM) conducted by the U.S. Census Bureau. State-level totals (which the Census Bureau refers to as “AS-3” data) are reported in the yearly volumes of the ASM publication. From 1994 onward, these data also can be found in the yearly ASM Geographic Area Statistics (ASM-GAS) publications. Hereafter, we will refer to the ASM data on state-level totals for all years as the ASM-GAS data. The ASM data are collected from a large, representative sample of manufacturing establishments with one or more paid employees. The ASM manufacturing sector corresponds to NAICS sectors 31 to 33.

4.1 The Capital Stock -- $K_{i,t}$

The $K_{i,t}$ series is measured by the real (constant-cost) replacement value of equipment (excluding software) and structures, and this series is constructed from the following perpetual inventory formula,

$$K_{i,t} = K_{i,1981}(1-\delta_{mfg,t})^{t-1981} + I_{i,t} \qquad t = 1982,...,T \ ,$$

where $K_{i,1981}$ is the initial (1981) value of the real capital stock, $\delta_{mfg,t}$ is the geometric rate of economic depreciation (hence $(1-\delta_{mfg,t})$ is the survival rate), and $I_{i,t}$ is real total capital expenditure. The capital stock is dated end-of-period (EOP). Each component determining the capital stock is discussed in the following subsections.

4.2 The Initial Value Of The Capital Stock -- $K_{i,1981}$

The $K_{i,1981}$ series is measured by the book value of the capital stock adjusted for inflation,

$$K_{i,1981} = K^{BV}_{i,1981} * \left(K^{CoC}_{mfg,1981} / K^{HC}_{mfg,1981}\right),$$

where $K^{BV}_{i,1981}$ is the book value (historical-cost) of the capital stock for state *i*, $K^{CoC}_{mfg,1981}$ is the constant-cost value of the capital stock for the manufacturing sector, and $K^{HC}_{mfg,1981}$ is the historical-cost value of the capital stock for the manufacturing sector. All capital stock series are end-of-period. Inflation drives a wedge between book value capital stocks (based on the original purchase cost of investment) and real capital stocks useful in economic analyses. The $\left(K^{CoC}_{mfg,1981} / K^{HC}_{mfg,1981}\right)$ ratio provides an approximate adjustment for the inflation wedge based on national manufacturing industry data.

The $K^{BV}_{i,1981}$ series is obtained from ASM. The $K^{CoC}_{mfg,\tau}$ series is the product of a quantity index and a base year value that converts the index into a real stock,

$$K^{CoC}_{mfg,1981} = \text{INDEXK}^{CoC}_{mfg,1981} * K^{CuC}_{mfg,2000},$$

where $\mathrm{INDEXK}^{CoC}_{mfg,1981}$ is the 1981 value of the chain-type quantity index for the real capital stock and $K^{CuC}_{mfg,2000}$ is the base year (2000) value for the current-cost value of the capital stock for the manufacturing sector. The $\mathrm{INDEXK}^{CoC}_{mfg,1981}$ is obtained from FIXED, Table 4.2, line 7, and this series is divided by 100. The $K^{CuC}_{mfg,2000}$ datapoint is obtained from FIXED, Table 4.1, line 7. The $K^{HC}_{mfg,1981}$ series is obtained from FIXED, Table 4.3, line 7.

4.3. The Rate Of Economic Depreciation – $\boldsymbol{\delta_{mfg,t}}$

The $\delta_{mfg,t}$ series is measured by the flow of annual depreciation divided by the capital stock existing at the beginning of the year,

$$\delta_{mfg,t} = \frac{D^{CuC}_{mfg,t}}{K^{CuC}_{mfg,t-1}},$$

where $D^{CuC}_{mfg,t}$ is the current-cost flow of depreciation in manufacturing industries and $K^{CuC}_{mfg,t-1}$ is the current-cost capital stock in manufacturing industries. The $D^{CuC}_{mfg,t}$ series is obtained from FIXED, Table 4.4, line 7. The $K^{CuC}_{mfg,t-1}$ series is obtained from FIXED, Table 4.1, line 7. See FRAUMENI for an excellent introduction to the theoretical and empirical literature on economic depreciation and JORGENSON-2 for an analysis showing that, even if capital depreciates according to a non-geometric pattern, long-run replacement requirements tend to a geometric pattern.

4.4. Real Total Capital Expenditure – $I_{i,t}$

The $I_{i,t}$ series is defined as nominal capital expenditures deflated by a price index,

$$I_{i,t} = \frac{I\$_{i,t}}{P^{I}_{mfg,t}},$$

$$I\$_{i,t} = I\$^{NEW}_{i,t} + I\$^{USED}_{i,t},$$

where $I\$_{i,t}$, $I\$^{NEW}_{i,t}$, and $I\$^{USED}_{i,t}$ are total, new, and used nominal capital expenditures, respectively, and $P^{I}_{mfg,t}$ is the price deflator for investment for the manufacturing sector. The $I\$_{i,t}$ and $P^{I}_{mfg,t}$ series are discussed in the following subsections.

4.4.1. Total Nominal Capital Expenditure – $I\$_{i,t}$

The $I\$_{i,t}$ series represents nominal expenditures on equipment (excluding software) and structures. The series is obtained directly from ASM-GAS (e.g, in 2004, the data are published in Table 2, column I).[34]

4.4.2. Price Deflator For Investment – $P^{I}_{mfg,t}$

The price deflator for investment is constructed as an implicit deflator,

$$P^{I}_{mfg,t} = \frac{I\$_{mfg,t}}{I_{mfg,t}},$$

where $I\$_{mfg,t}$ and $I_{mfg,t}$ are nominal and real total capital expenditures, respectively, for the manufacturing sector.

The $I_{mfg,t}$ series is the product of a quantity index and a base year value that converts

[34] We uncovered an obvious data error in the ASM regarding nominal capital expenditures in 1996 for Ohio and the sum-of-states national total. Ohio published value was over 400% of Ohio's typical levels and the resulting national total was inconsistent with the national total published in the alternative ASM publication, ASM-SIGI. We filled in the 1996 Ohio data point by simply taking national manufacturing capital expenditures from the alternative ASM publication, ASM-SIGI, and subtracting the sum of capital expenditures from all other states.

the index into real investment expenditures,

$$I_{mfg,t} = INDEXI_{mfg,t} * I\$_{mfg,t=2000},$$

where $INDEXI_{mfg,t}$ is the chain-type quantity index for real investment expenditures and $I\$_{mfg,t=2000}$ the base year value for current investment expenditures. The $INDEXI_{mfg,t}$ is obtained from FIXED, Table 4.8, line 7, and this series is divided by 100.

5. ITC: Investment Tax Credit Rate

The state investment tax credit is a credit against state corporate income tax liabilities. In general, the effective amount of the investment tax credit is simply the legislated investment tax credit rate ($ITC_{i,t}^{L,S}$) multiplied by the value of capital expenditures put into place within the state in a tax year. The effective rate is lower than the legislated rate in a handful of states for two reasons. First, five states (Connecticut, Idaho, Maine, North Carolina, and Ohio) permit the state investment tax credit to be applied only to equipment. Since equipment investment is approximately 85% of ASM total national investment, we multiply $ITC_{i,t}^{L,S}$ by 0.85 for these five states. Second, states generally require basis adjustments deducting the amount of the credit from the asset basis for depreciation purposes; this adjustment is considered in the subsection on the Present Value of Tax Depreciation Allowances.

We extend the 1963-2004 state panel data on $ITC_{i,t}^{L,S}$ from Chirinko and Wilson (2008) through 2006. The original and extended data are obtained directly from states' online corporate tax forms and instructions. For most states with an investment tax credit, both current and historical credit rates are provided in the current year instructions (since companies applying for a credit based on some past year's investment apply that year's credit rate rather than the current rate). In those few cases where some or all historical rates were missing from the online forms and instructions, the missing rates are obtained via direct communication with the state's department of taxation. In some states, the legislated investment tax credit rate varies by the level of capital expenditures; we use the legislated credit rate for the highest tier of capital expenditures.

6. PERS: Personal Income Tax Rate

The personal income tax rate is measured by the marginal tax rate for the median household computed from the NBER TaxSim simulator. TaxSim generates the marginal state tax rate for each state-year for a hypothetical taxpayer who files jointly, has no dependents, and has household income equal to the 50th percentile nationally for that year.

7. PREFERENCES: Voter Preferences

Voter preferences are measured by political outcomes. Specifically, we measure the following two political outcomes as indicator variables:

(a) the governor is Republican (R). (The complementary class of politicians is Democrat (D) or Independent (I). An informal examination of the political landscape suggests that Independents tend to be more closely aligned with the Democratic Party. We thus treat D or I politicians as belonging to the same class, DI);

(b) the majority of both houses of the legislature are R;

The PREFERENCES variable takes on one of three values:

0 if the governor and the majority of both houses of the legislature are not R;

1/2 if the governor is R but the majority of both houses of the legislature are not R or if the governor is not R but the majority of both houses of the legislature are R;

1 if the governor and the majority of both houses of the legislature are R.

Data for these political variables come from the Statistical Abstract of the United States (U.S. Census Bureau (Various Years)).

8. POPULATION: Population

Population data are obtained from CENSUS.

9. TD: Tax Depreciation

Tax depreciation allowances accrue over the useful life of the asset. We have assumed that the present value of tax depreciation allowances, $TD_{i,t}$, is 0.70 for all s and t. We assume a slightly lower value than the average across asset types and years reported in GRAVELLE to adjust for the basis reduction by the amount of investment tax credits taken.

10. TWC: Tax Wedge on Capital

The price of capital (tax-adjusted) is defined as the product of three objects reflecting the purchase price of the capital good, the opportunity costs of holding depreciating capital, and taxes. This latter term comprises tax credits, tax deductions, and the tax rate on income, and we refer to these tax terms (less 1.0) as the tax wedge on capital,

$$TWC_{i,t} = \frac{1.0 - ITC_{i,t} - CIT_{i,t} * TD}{1 - CIT_{i,t}} - 1.0 \ .$$

In this paper, we define $TWC_{i,t}$ only in terms of state tax variables.

Note that the user cost of capital, which was introduced by JORGENSON-1 in 1963 and extended by, among others, HALL-JORGENSON, GRAVELLE, JORGENSON-YUN, and KING-FULLERTON, equals the price of capital divided by the price of output.

11. $\omega_{i,j}$: Spatial Lag Weights

The spatial lag weights are measured by the distance between state population centroids (data are from CENSUS) and by commodity trade flows (data are from TRANSPORT).

12. Legend

ASM: CENSUS, *Annual Survey of Manufactures, Complete Volume* (Various Years).

ASM-GAS: CENSUS, *Annual Survey of Manufacturers, Geographic AreaStatistics* (Various Years). Publications for the years 1994 to 2004 (except 1997 and 2002) are available online. These data are published on an establishment basis. The data are obtained from electronic or paper documents depending on the time period: 2004 (Census website); 2003 to 1972 (CD's purchased from Census); 1971 to 1963 (paper copies). URL: http://www.census.gov/mcd/asm-as3.html.

ASM-SIGI: CENSUS, *Annual Survey of Manufacturers, Statistics for Industry Groups and Industries* (1996). URL: http://www.census.gov/mcd/asm-as1.html.

BDF: Bruce, Donald, Deskins, John, and Fox, William F., "On The Extent, Growth, and Efficiency Consequences of State Business Tax Planning," mimeo, University of Tennessee, 2005.

BOTS: The Council of State Governments, *The Book of the States* (The Council of State Governments : Lexington, Kentucky, Various Issues).

CBP: CENSUS, *County Business Patterns.* URL: http://www.census.gov/epcd/cbp/download/cbpdownload.html.

CENSUS: Bureau of the Census, U.S. Department of Commerce. URL: http://www.census.gov.

CESW: Cornia, Gary; Edmiston, Kelly; Sjoquist, David L.; and Wallace, Sally, "The Disappearing State Corporate Income Tax," *National Tax Journal* 58 (March 2005), 115-138.

FIXED: BEA, *Standard Fixed Asset Tables.*
URL: http://www.bea.gov/bea/dn/FA2004/SelectTable.asp.

FRAUMENI: Fraumeni, Barbara M., "The Measurement of Depreciation in the U.S. National Income and Product Accounts," *Survey of Current Business* 77 (July 1997), 7-23.

GRAVELLE: Gravelle, Jane G., *The Economic Effects of Taxing Capital Income* (Cambridge: MIT Press, 1994) plus updates kindly provided by Jane Gravelle.

HALL-JORGENSON: Hall, Robert E., and Jorgenson, Dale W., "Application of the Theory of Optimum Capital Accumulation," in Gary Fromm (ed.), *Tax Incentives and Capital Spending* (Washington: Brookings Institution, 1971), 9-60.

JORGENSON-1: Jorgenson, Dale W., "Capital Theory and Investment Behavior," *American Economic Review* 53 (May 1963), 247-259; reprinted in *Investment,Volume 1: Capital Theory and Investment Behavior* (Cambridge: MIT Press, 1996), 1-16.

JORGENSON-2: Jorgenson, Dale W., "The Economic Theory of Replacement and Depreciation," in Willi Sellakaerts (ed.), *Econometrics and Economic Theory: Essays in Honour of Jan Tinbergen* (London: MacMillan, 1974), 189-222.

JORGENSON-YUN: Jorgenson, Dale W., and Yun, Kun-Young, *Investment Volume 3: Lifting the Burden: Tax Reform, the Cost of Capital, and U.S. Economic Growth* (Cambridge: MIT Press, 2001).

KING-FULLERTON: King, Mervyn A., and Fullerton, Don (eds.), *The Taxation of Income from Capital* (Chicago: University of Chicago Press (for the NBER), 1984).

OMER: Omer, Thomas C., and Shelley, Marjorie K., "Competitive, Political, and Economic Factors Influencing State Tax Policy Changes," *Journal of the American Tax Association*, 26 (2004), 103-126.

REA: Bureau of Economic Analysis, *Regional Economic Accounts*
URL: http://www.bea.gov/regional.

SFFF: American Council on Intergovernmental Affairs, *Significant Features of Fiscal Federalism* (Washington, DC: American Council on Intergovernmental Affairs, Various Issues). URL (e.g., 1987):
http://www.library.unt.edu/gpo/ACIR/SFFF/SFFF-1988-Vol-1.pdf.

STC CENSUS, State Government Tax Collections report, various years.
URL: http://www.census.gov/govs/www/statetax.html.

STH: Commerce Clearing House, *State Tax Handbook* (Chicago: Commerce Clearing House, Various Issues).

TAXFDN: Tax Foundation web site.
URL: http://www.taxfoundation.org.

TRANSPORT: The U.S. Bureau of Transportation Statistics, *1997 Survey of Commodity Flows*.

***** NOT FOR PUBLICATION *****

Appendix B: Properties Of The Capital Mobility Function

This appendix provides some analytic details concerning the properties of the capital mobility function (equation (2)) used in this paper. This function allows for the possibility that, owing to a variety of frictions, the net-of-tax returns on capital may differ across jurisdictions. This appendix demonstrates that the capital mobility function and its partial derivatives are consistent with the implications from the standard constraint equating net-of-tax returns across jurisdictions.

Equation (2) is reproduced here as follows,

$$K = K[\tau : \tau^f, x_k, x_k^f], \tag{B-1}$$

$$K_\tau[.] = -K_{\tau^f}[.] < 0 .$$

The relation between the net-of tax returns in the home and foreign jurisdictions is as follows,

$$(1-\tau)\ F'[K] + \Delta = (1-\tau^f)\ \Im'[K^f], \tag{B-2}$$

where Δ is a wedge that represents a variety of frictions preventing equalization of net-of-tax returns across jurisdictions, $F'[K]$ and $\Im'[K^f]$ are the marginal products of capital for the home and foreign jurisdictions, respectively, and the production functions for both jurisdictions are subject to the Inada conditions (which guarantee that equation (B-2) will hold for some capital allocation). We assume that there is a fixed amount of capital ($\overline{K}$) that is allocated between the home and foreign jurisdictions,

$$\overline{K} = K + K^f . \tag{B-3}$$

Substituting equation (B-3) into (B-2), differentiating the resulting expression by K, τ, and τ^f, and rearranging, we obtain the following derivatives,

$$K_\tau[.] \equiv \frac{dK}{d\tau} = \frac{F'[.]}{(1-\tau)\, F''[.] + (1-\tau^f)\, \Im''[.]} < 0, \qquad \text{(B-4a)}$$

$$K_{\tau^f}[.] \equiv \frac{dK}{d\tau^f} = \frac{-\Im'[.]}{(1-\tau)\, F''[.] + (1-\tau^f)\, \Im''[.]} > 0, \qquad \text{(B-4b)}$$

where we have assumed that the production functions exhibit diminishing marginal products ($F''[.] < 0, \Im''[.] < 0$). If the production functions are identical across jurisdictions, then $K_\tau[.] = -K_{\tau^f}[.]$.

***** NOT FOR PUBLICATION *****

Appendix C: Tax Competition In A Direct Utility Model

This appendix analyzes the tax competition model developed in Section II with the indirect utility function (equation (8)) replaced by the following direct utility function defined in terms of c and g,

$$U\left[c,g\right] \; = \; \Upsilon \, c^{\kappa} \, g^{\tilde{\psi}} \, . \tag{C-1}$$

It proves convenient to rewrite equation (C-1) in terms of the private/public goods mix variable,

$$U\left[\zeta,g\right] \; = \; \Upsilon \, \zeta^{\kappa} \, g^{\psi} \qquad\qquad \psi \equiv \tilde{\psi} + \kappa \, . \tag{C-2}$$

The optimization problem facing policymakers is to choose τ in order to maximize equation (C-2) constrained by equations (3), (5), and (7) reproduced here in abbreviated form for convenience,

$$y \; = \; G\left[\tau : \tau^{f}, x_{k}, x_{k}^{f}\right], \qquad G_{\tau}[.] < 0, \tag{C-3}$$

$$g \; = \; \tau \pi y \, , \tag{C-4}$$

$$c / g \; \equiv \; \zeta \; = \; \left((1-\pi^{f}) / \tau \pi\right) - 1 \; \equiv \; H[\tau]. \qquad\qquad H_{\tau}[.] < 0 \tag{C-5}$$

To simplify the analysis, we have assumed that capital income taxation is the only sources of revenue in equation (C-4) (i.e., setting s = 0 in equation (5)). Substituting equation (C-3) into equation (C-4) to eliminate y, and restating ζ and g in equation (C-2) in terms of τ with equations (C-5) and the modified (C-4), respectively, the optimization problem can stated solely in terms of τ,

$$U\left[\tau\right] \; = \; \Upsilon \left\{H\left[\tau\right]\right\}^{\kappa} \left\{\tau \pi G\left[\tau\right]\right\}^{\psi} \tag{C-6}$$

Differentiating equation (C-6) with respect to τ and rearranging, we obtain the following equation determining the optimal τ implicitly,

$$\tau^* = \left(1 - \frac{\kappa}{\psi\ (1-\Gamma[\tau^* : \tau^f])}\right)\left(\frac{(1-\pi^f)}{\pi}\right). \tag{C-7}$$

where Γ is the elasticity of output with respect to the capital tax rate (reflecting both the sensitivity of capital flows to the capital tax rate and output to the capital stock; see equation (11b) for further details). Assume that Γ is constant. In this case, equation (C-7) has the reasonable properties that the optimal capital income tax rate depends (1) negatively on the relative utility weight on private goods ($\kappa / \psi = \kappa / (\kappa + \tilde{\psi})$), (2) negatively on the share of capital income (thus requiring a lower capital tax rate to collect a given amount of revenue), and (3) negatively on Γ (reflecting the amount of capital outflow for a given change in τ).

Differentiating equation (C-7) with respect to τ and τ^f with the chain rule and rearranging yields the following reaction function,

$$\frac{d\tau}{d\tau^f} = \frac{\delta^* \Gamma'}{\left(1+\delta^* \Gamma'\right)}, \tag{C-8a}$$

$$\delta \equiv \left(\kappa / \psi\ \right)\left((1-\pi^f)/\pi\right)\left(1-\Gamma[.]\ \right)^{-2} > 0, \tag{C-8b}$$

$$\Gamma' \equiv d\Gamma / d\tau. \tag{C-8c}$$

Relative to our preferred reaction function derived from an indirect utility function, equation (C-8) is restrictive because its sign depends on the direction of change in an elasticity, a derivative that is unrelated to traditional economic mechanisms and intuition. Note that, if the production and capital flow functions constituting Γ have constant elasticities, then $\Gamma' = 0$ and $d\tau / d\tau^f > 0$. Most importantly, the direct utility model does not allow for the possibility that the private/public good mix is sensitive to income. Such a restriction is relaxed in the indirect utility model and proves very important in understanding the slope of the reaction function.

***** NOT FOR PUBLICATION *****

Appendix D: The Existence Of An Equilibrium Tax Rate

This appendix provides some analytic details concerning the existence of an equilibrium tax rate (τ^*) in the indirect utility model and its relation to the pre-tax capital income share and the rate of sales taxation. We analyze a symmetric equilibrium between home and foreign jurisdictions. We begin with the three relations that summarize the content of the theoretical model presented in Section II.A,

$$y \;=\; F[K] \;=\; F\Big[K[\tau : \tau^f x_k, x_k^f]\Big] \;=\; G[\tau : \tau^f x_k, x_k^f] \;, \tag{D-1}$$

$$G_\tau[.] < 0, \;\; G_{\tau^f}[.] > 0.$$

$$c/g \;\equiv\; \zeta \;=\; \Big((1-\pi^f)/(\tau\pi + s)\Big) - 1 \;\equiv\; H[\tau], \tag{D-2}$$

$$H_\tau[.] < 0\,.$$

$$c/g \;\equiv\; \zeta \;=\; \zeta[y(1-\pi^f) : x_\zeta] \;=\; \xi\,\Big(y(1-\pi^f)\Big)^{\eta_{\zeta,y}}\,, \tag{D-3}$$

$$\xi \equiv \Big(\xi_c\theta_c / \xi_g\theta_g\Big)\Big(p_c^{-(\theta_c+1)} / p_g^{-(\theta_g+1)}\Big) > 0,$$

$$\eta_{\zeta,y} \equiv \theta_c - \theta_g \;>=<\; 0.$$

where equation (D-1) is equation (3) representing the production function and the mobile capital stock, equation (D-2) is equation (7) representing the aggregate and government budget constraints, and equation (D-3) is equation (9) representing optimized choices of private and public goods.

Under the symmetry assumption, no capital flows between jurisdictions because the tax rates are equal. Thus, equation (D-1) implies that the level of output in each country is constant, $y = \overline{y}$. Substituting this constant into equation (D-3) and eliminating ζ with equation (D-2), we obtain the following solution for τ^*

$$\left((1-\pi^{f})/(\tau^{*}\pi+s)\right)-1 \;=\; \xi\left(\overline{y}(1-\pi^{f})\right)^{\eta_{\zeta,y}},$$

$$\rightarrow$$

$$\tau^{*} \;=\; \left((1-\pi^{f})/\pi\right)\left(1+\xi\left(\overline{y}(1-\pi^{f})\right)^{\eta_{\zeta,y}}\right)^{-1} - \left(s/\pi\right), \tag{D-8}$$

$$\rightarrow$$

$$\tau^{*} \;=\; ((1-\pi^{f})/\pi)/\left(1+\zeta\right) - \left(s/\pi\right).$$

$$= \left((1-\pi^{f})/\left(1+\zeta\right) - s\right)\;/\;\pi$$

Since representative estimates of ζ and s are 3.678 and 0.025, respectively, $\tau^{*} > 0$ is ensured because the maximum value of π^{f} is π (the capital income share).

Equation (D-8) establishes that there is a negative relation between τ^{*} and the pre-tax capital income share (π) and the rate of sales taxation (s).

***** NOT FOR PUBLICATION *****

Appendix E: A Distributed Lag Reaction Function

This appendix combines a static tax reaction function with a partial adjustment model to derive the distributed lag reaction function that generates the benchmark results in this paper.

The flow of capital among states may occur gradually over several years, and hence the observed τ_t will differ from the desired home state capital income tax rate, $\tau_t^{\#}$. To allow for the gradual response of τ_t, we adopt the following partial adjustment model,

$$\tau_t = \lambda\left(\tau_t^{\#} - \tau_{t-1}\right) + \tau_{t-1} + v_t, \tag{E-1}$$

where λ is a parameter determining how much of the discrepancy between the long-run and lagged τ's will be eliminated in period t, and v_t is a stochastic shock. The *i* subscripts have been omitted for convenience. Lagging equation (E-1) one period and successively substituting the lagged equations into equation (E-1) yields the following equation,

$$\tau_t = \lambda \sum_{j=0}^{J} (1-\lambda)^j \tau_{t-j}^{\#} + \sum_{j=0}^{J} (1-\lambda)^j v_{t-j} + (1-\lambda)^T \tau_{t-J}. \tag{E-2}$$

As $J \to \infty$, the last term vanishes. We use the static relation (equation (14)) to define $\tau_t^{\#}$,

$$\tau_t^{\#} = \alpha \tau_t^f + \beta x_t + u_t. \tag{E-3}$$

Substituting equation (E-3) into (E-2) and rearranging, we obtain the following distributed lag model,

$$\tau_t = \sum_{j=0}^{\infty} \tilde{\alpha}_j \tau^f_{t-j} + \sum_{j=0}^{\infty} \tilde{\beta}_j x_{t-j} + w_t, \tag{E-4}$$

$$\tilde{\alpha}_j \equiv \lambda \alpha (1-\lambda)^j,$$

$$\tilde{\beta}_j \equiv \lambda \beta (1-\lambda)^j,$$

$$w_t \equiv \sum_{j=0}^{\infty} (1-\lambda)^j \left(v_{t-j} + \lambda u_{t-j} \right),$$

$$\sum_{j=0}^{\infty} \tilde{\alpha}_j = \lambda \alpha \sum_{j=0}^{\infty} (1-\lambda)^j = \alpha .$$

As shown on the last line of Equation (E-4), the estimated coefficients on the τ^f_{t-j}'s sum to α, the slope of the reaction function that is the prime focus of this paper.

Equation (E-4) is the basis for our estimation, which relies on a less general form of this equation in two dimensions. First, the distributed lags are truncated at no more than four periods. Lagged dependent variables allow us to capture the effects of lags further back in time, and this model is discussed in Appendix G. Second, the $\tilde{\alpha}_j$'s and $\tilde{\beta}_j$'s are estimated freely, as we do not impose the parametric restrictions defined in equation (E-4).

There are two other differences between the distributed lag reaction function and the econometric equation that generates our benchmark results. In order to conserve degrees of freedom, we lag the x variables only one period. An implication of equation (E-4) is that the composite error term will be correlated with all of the τ^f_{t-j}'s, not just τ^f_t. We explore the impact of this potential correlation on the coefficients of interest by instrumenting the lagged foreign tax rate variables with lags of our preferred instrument set (i.e., for a given n, $\tau^f_{i,t-n}$ is instrumented by $z^*_{\tau,i,t-n}$ for n=1,4). (We estimate the time fixed effects model because estimation of the CCE model would be computationally demanding with this expanded number of instruments.) Standard errors increase sharply and do not permit us to make any meaningful inferences. This result is traceable to a small amount of incremental information in $z^*_{\tau,i,t-n}$ relative to $z^*_{\tau,i,t}$. The eigenvalue for assessing instrument relevance is less than one for each model (i.e., n=1, 2, 3, and 4), far below the conventional critical value of 11.29 (see Section

III.C). Our instruments do not have sufficient variation to accurately discriminate among lagged τ^{f}_{t-j}'s.

The second difference is that we do not impose the parametric restrictions in equations (E-4). While efficiency would be enhanced, a less restricted specification continues to generate unbiased and consistent estimates. We prefer a less restricted form to facilitate computation of the CCE estimator and our instrument search algorithm.

***** NOT FOR PUBLICATION *****

Appendix F: The Three-Step Procedure For Estimating The Non-Linear CCE Model

This appendix presents a more concise and formal statement of our three-step procedure for obtaining consistent estimates with the non-linear CCE estimator described in Section III.C. We begin by reproducing equation (21) as equation (F-1),

$$\begin{aligned}\tau_{i,t} &= \alpha_0 \hat{\tau}^{f}_{i,t} + \sum_{n=1}^{N} \alpha_n \tau^{f}_{i,t-n} + x_{i,t}\beta + \varphi_i + \varepsilon_{i,t} \\ &\quad + \gamma_i \left(\bar{\tau}_t - \alpha_0 \bar{\hat{\tau}}^{f}_{t} - \sum_{n=1}^{N} \alpha_n \bar{\tau}^{f}_{t-n} - \bar{x}_t \beta \right),\end{aligned} \tag{F-1}$$

and rewriting it in the following concise notation,

$$\begin{aligned}\tau_{i,t} &= Q\left[\Pi^m, \Omega^n, \gamma^o\right] \\ &\qquad \Pi^m = \left\{\text{all } \alpha_i \text{ 's and } \beta \text{ from the first line in equation (F-1)}\right\} \\ &\qquad \Omega^n = \left\{\text{all } \alpha_i \text{ 's and } \beta \text{ from the second line in equation (F-1)}\right\} \\ &\qquad \gamma^o = \left\{\text{all } \gamma_i \text{ 's}\right\}\end{aligned} \tag{F-2}$$

where the m, n, and o superscripts index iterations.

Step 1 estimates the Π and Ω parameters pre-setting γ to 1.0,

$$\tau_{i,t} = Q\left[\Pi^1, \Omega^1, \gamma^o = 1\right]. \tag{F-3}$$

Step 2 estimates the Π and γ parameters pre-setting the Ω parameters to the estimates obtained in Step 1,

$$\tau_{i,t} = Q\left[\Pi^2, \Omega^1, \gamma^2\right], \tag{F-4}$$

and then iterates as follows,

$$\tau_{i,t} = Q\left[\Pi^3, \Omega^2, \gamma^3\right],$$

$$\tau_{i,t} = Q\left[\Pi^4, \Omega^3, \gamma^4\right], \tag{F-5}$$

………………………...

until converge is achieved for each individual hth parameter $\pi_h \in \Pi$ and $\omega_h \in \Omega$ according to the following convergence criteria at the pth iteration,

$$\left|\pi_h^p / \omega_h^p - 1\right| \leq 0.01. \tag{F-6}$$

Step 3 estimates the Π and Ω parameters pre-setting the γ parameters to the consistent estimates obtained at the conclusion of Step 2,

$$\tau_{i,t} = Q\left[\Pi^{p+1}, \Omega^{p+1}, \gamma^p\right]. \tag{F-7}$$

Equation (F-7) is linear in the parameters and is the basis for the CCE estimates presented in the paper.

***** NOT FOR PUBLICATION *****

Appendix G: Notes on the Specification of Dynamic Models

This appendix provides the details supporting our discussion in Section V.B that A) the standard lagged dependent variable (LDV) model is nested within a more general dynamic model that includes no LDV but an infinite number of time lags of the independent variables and B) a restricted version of this latter model can be estimated by including *N* lags of the independent variables and the *N+1st* lag of the LDV.

An "expanded" specification of our preferred model includes lags of all independent variables and is written as follows,

$$\tau_t = \sum_{n=0}^{N} \left(x_{t-n} \beta_n \right) + \varepsilon_t \tag{G-1}$$

where one of the variables in the x vector is the spatial lag of τ and *N* can go to infinity. (Note state subscripts have been omitted for expositional convenience.) Equation (G-1) is more general than our preferred specification (equations (17), (19), or (21)) because it contains additional lags. Equation (17) can be obtained from equation (G-1) by setting $\beta_n = 0$ for $n \geq 1$.

Now consider the lagged dependent variable (LDV) model:

$$\tau_t = \rho\tau_{t-1} + x_t\beta + \vartheta_t , \tag{G-2}$$

where ϑ_t is an error term. The LDV can be eliminated by lagging this equation one period and substituting it into equation (G-2). The resulting equation contains the regressors x_t, x_{t-1}, and τ_{t-2}. The latter variable is eliminated by repeating the above procedure by lagging this transformed equation one period. If the procedure is repeated up to the *N+1st* period, we obtain the following equation,

$$\tau_t = \rho^{N+1}\tau_{t-N-1} + \sum_{n=0}^{N}\left(x_{t-n}\,\gamma_n\right) + \varepsilon_t\,, \tag{G-3a}$$

$$\gamma_n = \rho^n\,\beta\,, \tag{G-3b}$$

$$\varepsilon_t = \sum_{n=0}^{N}\rho^n\,\vartheta_{t-n}\,. \tag{G-3c}$$

The only important difference between our preferred model (equation (G-1)) and the LDV model (equation (G-3)) is the LDV term $\rho^{N+1}\,\tau_{t-N}$. (The less important differences involve redefining the coefficient vector on the x variables (equation (G-3b)) and the serial correlation in the error term (equation (G-3c).) The central point is that what we are omitting from our model is NOT last year's tax policy (τ_{t-1}), since the effects of this term are captured by the one-year lags of the x variables (and lagged error terms), but rather a term capturing the determinants of tax policy lagged more than *N* periods in the past. (The serial correlation in the error term does not pose any bias problems as long as the x variables are exogenous or instrumented.)

As *N* goes to infinity, ρ^{N+1} goes to zero, and the LDV term vanishes. It is in this sense that the LDV model is nested within a more general model with an infinite number of lags of x_{t-n}. In practice, the question of whether our omission of the LDV term from our estimating equation poses any problem depends on how far back lags of x_{t-n} could reasonably be expected to affect tax policy. The results presented in the paper for models without an LDV are based on a maximum lag of N=4. However, we also have estimated a model in which we set N=3 and then include the dependent variable lagged four periods (i.e., the term $\rho^{3+1}\tau_{t-3-1}$. These results are discussed briefly in Section V.B.